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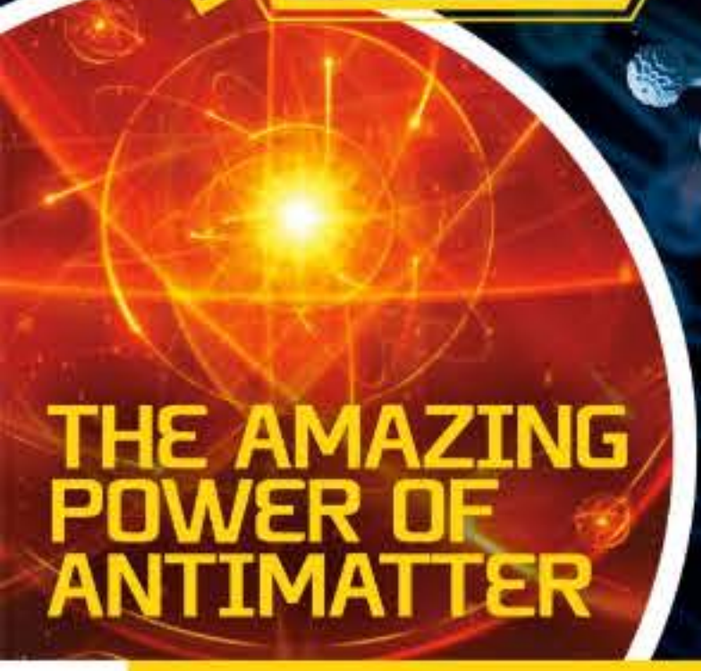

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WELCOME

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"As one of the world's blackest materials, it absorbs 99.96% of all visible light that hits it"

Super substances, page 22

We tend to take the properties of everyday things for granted: water will turn to steam when heated, glass is transparent, and a hot yellow plasma will erupt from the head of a match when struck. But scientists are still discovering materials with properties that seem to defy the laws of nature. In this issue of **How It Works**, we've brought you the 'super substances' with what we think possess almost magical properties – like the metal that melts in your hand – that in fact can be explained with science. Turn to page 22 to read all about them. Enjoy the issue!

Ben Biggs Editor

For exclusive **HIW** news and offers, sign up to our mailing list **howitworksdaily.com/newsletter**

Meet the team...

James
Production Editor
RFA Lyme Bay is more than just a transport ship – it can even flood itself to launch vessels into the ocean. See more on page 68.

Scott
Staff Writer
Meet the animals that have remained almost unchanged for millions of years, earning themselves the title of 'living fossils', on page 38.

Baljeet
Research Editor
What would aliens look like? On page 74 we explore how different conditions could help life on other planets to develop and thrive.

Duncan
Senior Art Editor
What could do the job of a tree 1,000 times better? The answer is a plastic, artificial tree – with seesaws. Find out how on page 56.

Ailsa
Staff Writer
From ancient winter celebrations to the festivities of today, we look at Christmas traditions around the world, on page 58.

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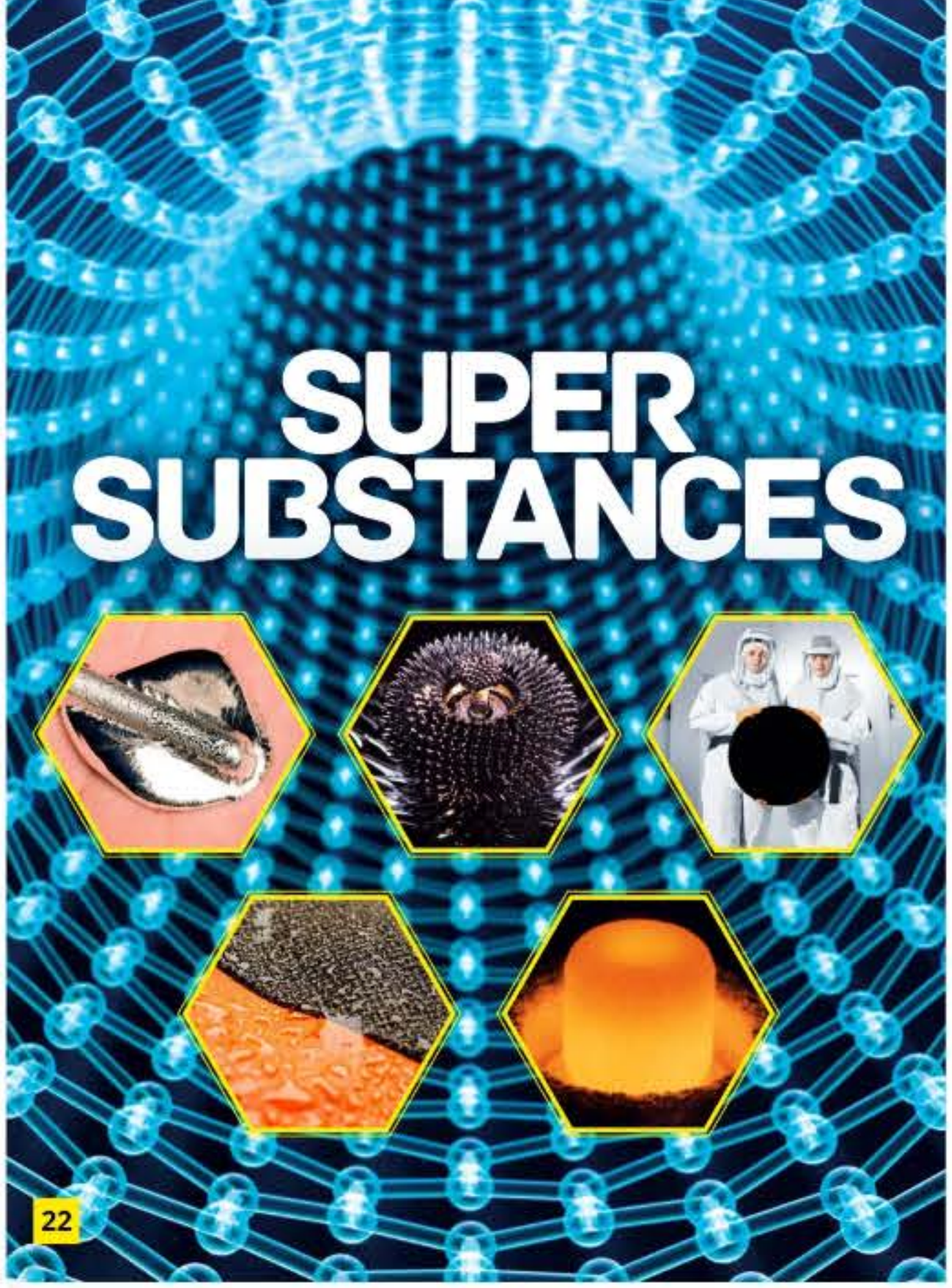
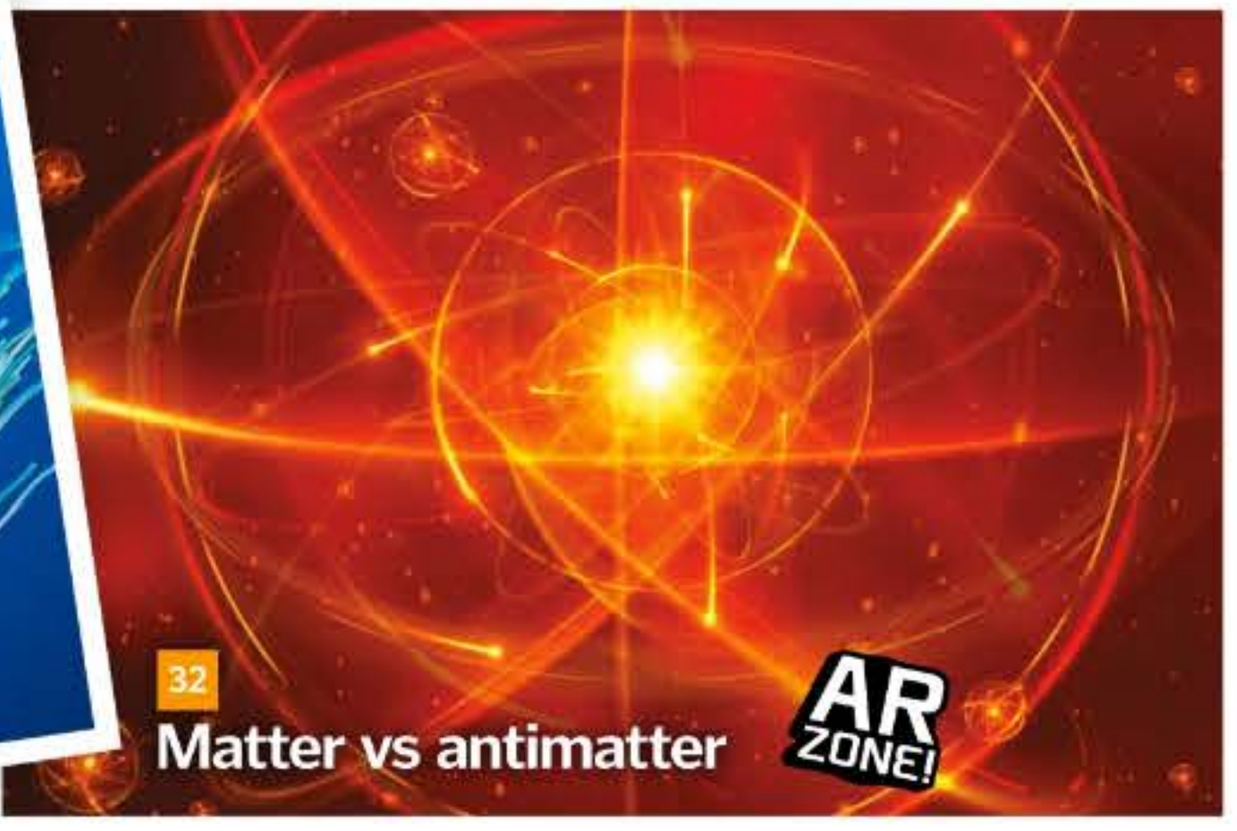




AR ZONE!

NEW

Download a free QR code reader app for your mobile phone if your phone hasn't got one (many iPhone and Android models have)

When you see the AR ZONE! logo at the top of a page, use your phone to scan the QR code, which looks like this

Hold your mobile device over the image and watch it come to life! Your device needs to be connected to the internet for this to work.

HOW THE AUGMENTED REALITY WORKS

After being launched by the QR code, the Zappar Web app reads anything you point your device's camera at 30 times a second, searching for distinctive shapes we've trained it to recognise. When it sees a familiar picture, it overlays the augmented reality 3D image we've previously uploaded on your screen.

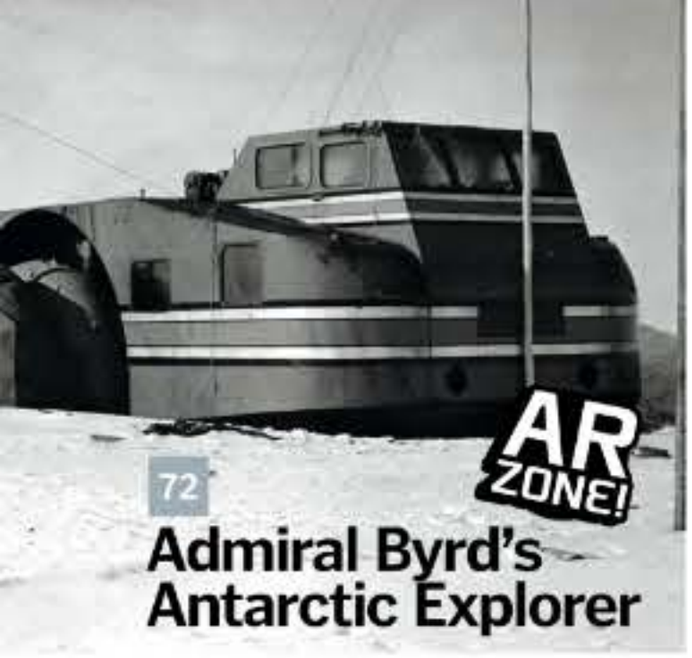
MEET THIS ISSUE'S EXPERTS...

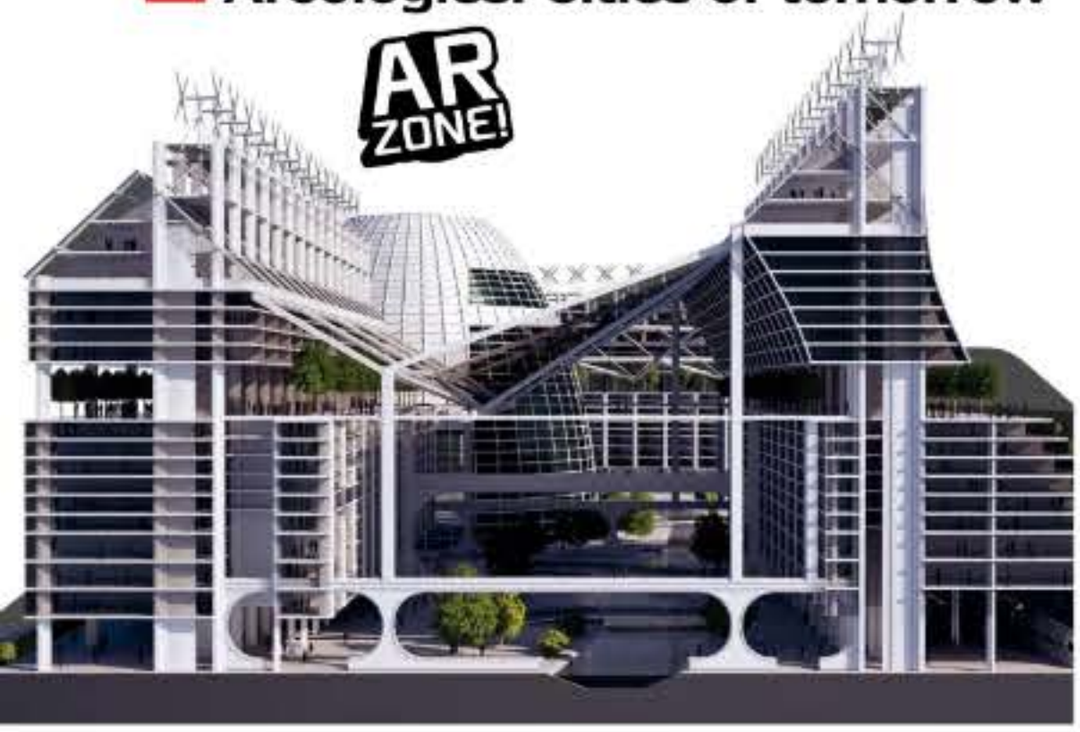
James Horton
Former **HIW** member James is a biochemist and biotechnologist. He is currently doing a PhD in machine learning and evolutionary theory.

Jo Stass
Writer and editor Jo is particularly interested in the natural world and learning about the latest in technological innovations.

Jodie Tyley
The former editor of **HIW** and **All About History** has tackled many topics in her career, from science fiction to science fact and Henry VIII to honey badgers.

Laura Mears
Biomedical scientist Laura escaped the lab to write about science and is now working towards her PhD in computational evolution.





REGULARS

Stephen Ashby
Stephen is a writer and editor with video games and computer tech expertise. He is endlessly intrigued by Earth science.

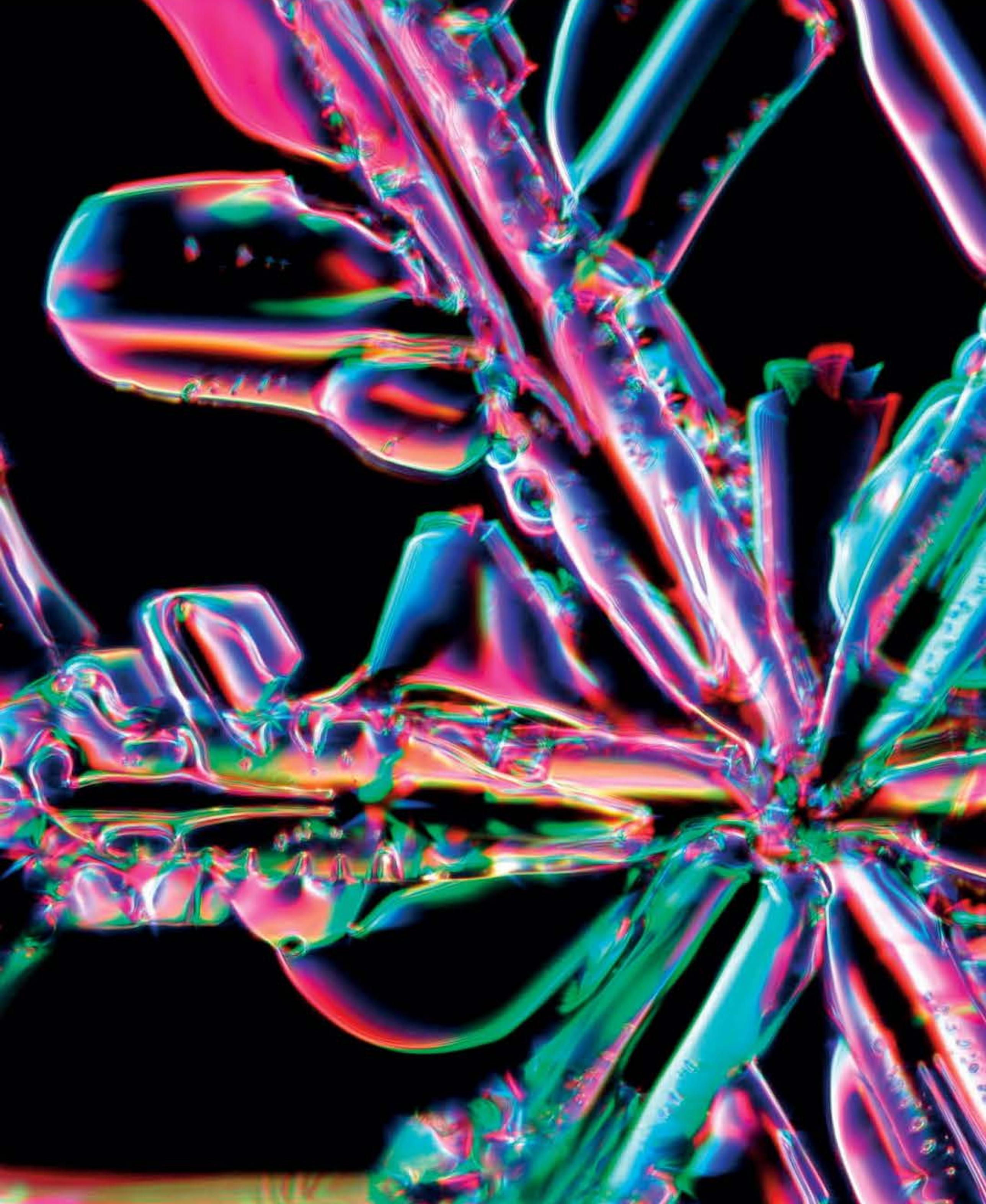
Steve Wright
Steve has worked as an editor on various publications. He particularly enjoys history feature writing and regularly writes literature and film reviews.

Andy Extance
Andy is a freelance science writer based in Exeter, UK. He previously worked in early-stage drug discovery research, followed by a brief stint in silicone adhesive and rubber manufacturing.

Lee Cavendish
As resident staff writer on our sister publication **All About Space**, Lee is an avid stargazer and is fascinated by pretty much all things space-related.

Dr Andrew May
Andrew has a PhD in astrophysics and 30 years in public and private industry. He enjoys space writing and is the author of several books.

Victoria Williams
Evolutionary Biologist and science writer Vicky is fascinated by the natural world and is happiest when she's in the outdoors.



Inside a snowflake

Taken using a scanning electron microscope (SEM), this image of a star-shaped (stellar) snowflake shows just how complex and unique each one of these flecks of ice can be. Beginning its life as a speck of dust or pollen high up in the chilling atmosphere, water molecules from cloud vapour condense on the speck, forming a droplet. On a journey down to the surface, this droplet freezes and gathers more moisture from the air, building over time into a snowflake. To form its star-like shape, atmospheric temperatures must be -10 to -20 degrees Celsius.

Northern light show

The aurora borealis over the Kirkjufell mountains, Iceland, sweeps across the northern sky. This glowing spectacle of blue and green ribbons is caused by the magic of magnetosphere disturbance. As solar flares penetrate the magnetosphere, Earth's magnetic shield, they collide with atmospheric molecules, creating photons. This awe-inspiring aurora was captured by Yevhen Samuchenko for The Royal Photographic Society's 2019 science photography competition. You can find out more at **rps.org/spotv.**

Illuminating London

Snapped from the International Space Station (ISS) on 27 September 2015, the metropolis of London is drenched in light during the early autumn. Cutting through this shining city, a shadow of the Thames river breaks up the 450 million lumens (equivalent to over 530,00 light bulbs) produced by the capital in a day. This image was taken by an Expedition 45 crew member aboard the ISS, around 400km above Earth. No special equipment was used to take the photo, just a Nikon D4 digital camera with a 400 millimetre lens.

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ANIMALS

Nuclear bunker ants turn to cannibalism

Words by **Mindy Weisberger**

In an abandoned nuclear bunker in western Poland, hundreds of thousands of worker ants that fell inside and were cut off from the main colony survived for years by eating the bodies of their dead.

When researchers visited the bunker in 2016, they described a community of nearly 1 million worker ants of the species *Formica polyctena*, or wood ants. The main colony teemed above ground on a mound atop the bunker's ventilation pipe; over the years, a steady stream of unlucky ants fell through the pipe and into the bunker. Since the pipe opened into the chamber from the ceiling, once the ants landed on the floor, they couldn't climb back out.

There was nothing for the ants to eat in the pitch-dark bunker; in 2016, the scientists hypothesised that the insects survived by cannibalising their dead comrades. Recently, the researchers returned to the bunker to continue their investigation of the trapped ants, looking for evidence that the insects were eating the corpses of their nestmates.

The bunker, once part of a nuclear base, is near the German border and was used by the Soviet military to store nuclear weapons from the late 1960s until 1992, the researchers reported in 2016.

"During an inspection made in July 2015, we estimated the size of the bunker 'population' of *Formica polyctena* to be at least several hundred thousand workers, perhaps close to a million," the scientists wrote online in the *Journal Of Hymenoptera Research*. While thousands of ants skittered over the bunker floor and walls, they were unable to walk on the ceiling where the pipe opening offered the only exit from their stone prison.

For the new study, the scientists collected more than 150 dead ants from 'cemeteries' – piles of bodies on the floor and near the walls around the bunker's main ant mound. Bodies with gnaw marks on their abdomens were thought to have been cannibalised; sure enough, a "vast majority" – 93 per cent – of the corpses showed signs of being eaten. In the bunker, the corpses served as a never-ending

Scientists found nearly 1 million wood ants trapped in a bunker formerly used by the Soviets to store nuclear weapons

Ants could climb the bunker's walls, but couldn't walk across the ceiling to reach the chamber's only exit

© Wojtech Stachan

HEALTH

New virus leaves scientists stumped

Words by **Yasemin Saplakoglu**

A newly discovered virus seems to lack the proteins needed to replicate itself. Yet somehow it's thriving, according to a new study.

To find this mysterious virus, a group of researchers in Japan have spent nearly a decade analysing pig and cow poo for novel viruses. These dirty environments, where lots of animals constantly interact, are a good place for viruses to quickly evolve, according to a statement from Tokyo University of Agriculture and Technology in Japan.

The researchers have found on farms several novel viruses that have recombined – meaning that two or more viruses have swapped genetic material. But they were particularly intrigued when they found a new type of enterovirus G (EV-G), which is composed of a single strand of genetic material. This new virus was formed from an enterovirus G and another type, called a torovirus.

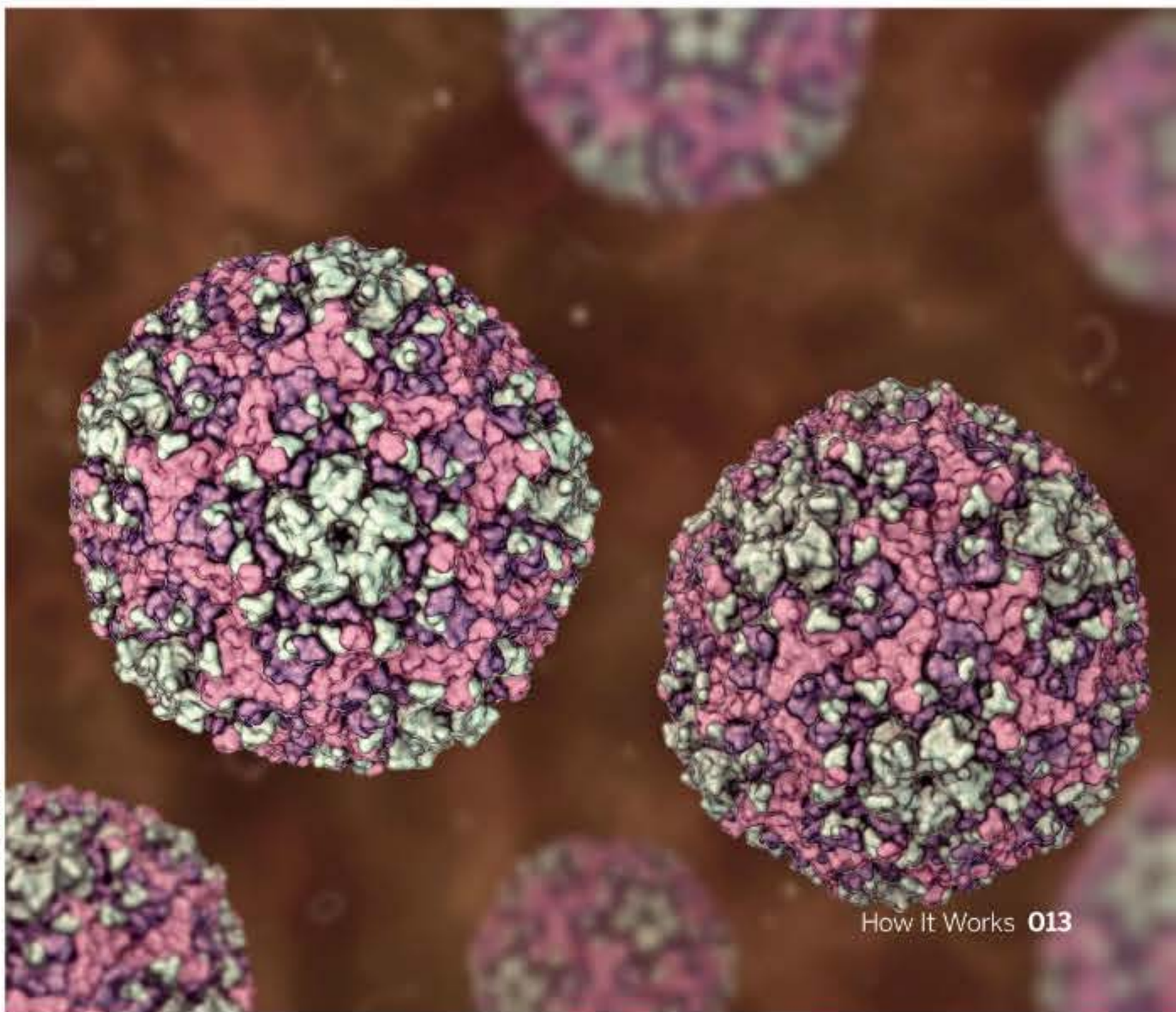
Mysteriously, the newly discovered microbe lacks a feature present in all other known viruses – so-called 'structural proteins' that help the parasite attach to and enter host cells, then replicate. Though the new enterovirus lacks the genes that code for these structural proteins, it does have a couple of "unknown" genes, according to the researchers.

"This is very strange," senior author Tetsuya Mizutani, the director at the Research and Education Center for Prevention of Global Infectious Disease of Animal (TUAT) in Japan, told **Live Science** in an email. Without structural proteins, the virus shouldn't be able to infect other cells, he added.

Yet, three years later, the researchers found the same virus in pig poo on the same farm, suggesting that the virus replicated in pigs. The scientists analysed poo they gathered from other farms and also found this virus present.

So, how does the virus, which they named type 2 EV-G, survive? Mizutani and his team hypothesise that the virus borrows structural proteins from other nearby viruses, called 'helper viruses'.

Now, Mizutani and his team are hoping to figure out which helper viruses enable 2 EV-G to survive, and discover exactly what the unknown genes do.



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buffet, enabling the ants to survive in a location where they would otherwise have starved, the researchers said.

Gruesome as those conditions were for the bunker ants, their story has a happy ending (at least for the ants that weren't eaten). The study authors also wondered if they could help the trapped ants find their way home, and in 2016 they installed a vertical 'boardwalk' – a wooden beam extending from the floor to the entrance of the pipe. When the scientists returned to the bunker in 2017, they found that most of the ants had taken advantage of the new escape route to gain their freedom.

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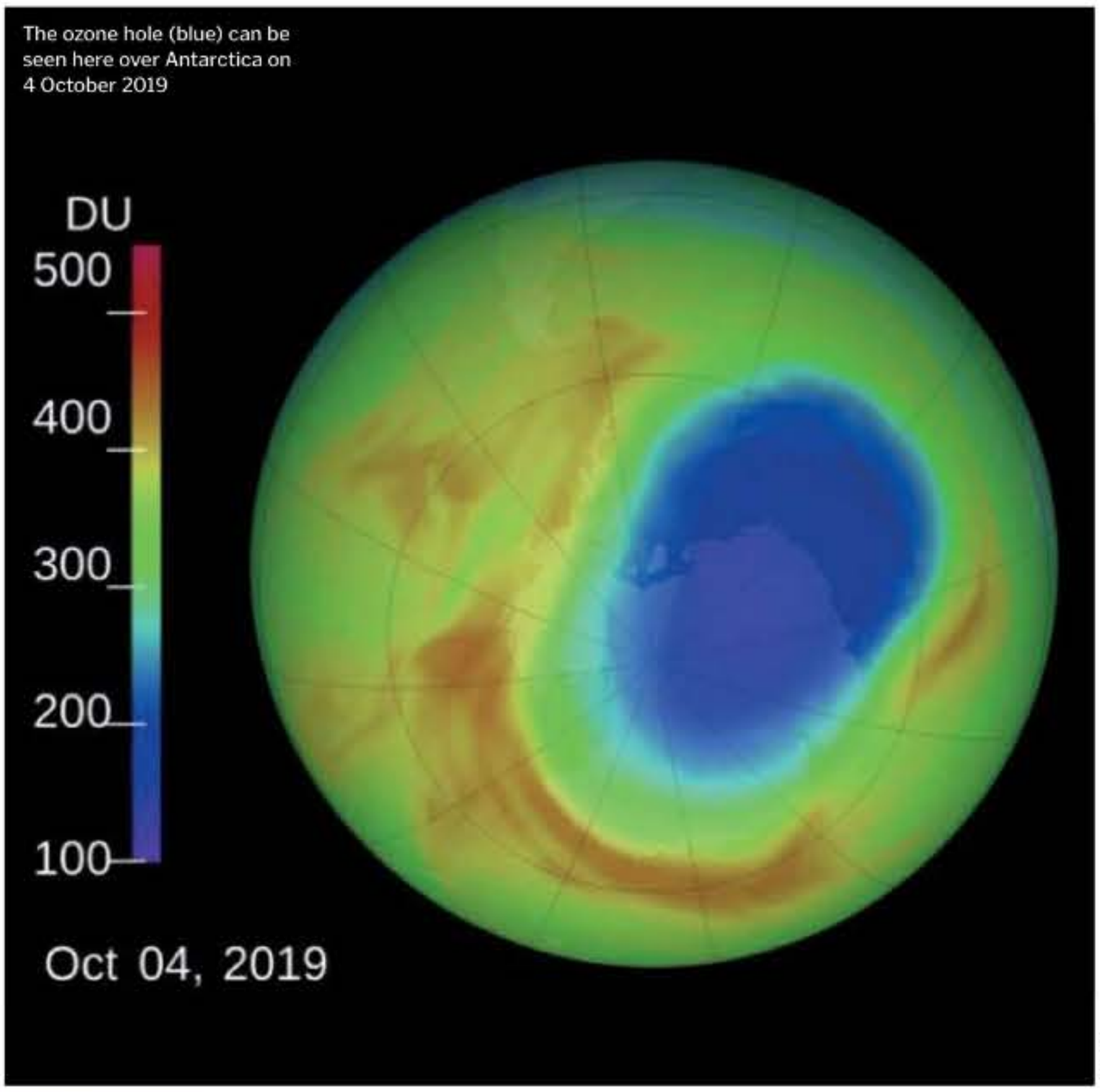


The ozone hole (blue) can be seen here over Antarctica on 4 October 2019

© NASA

PLANET EARTH

Ozone hole shrinks to record low

Words by **Jeanna Bryner**

The ozone hole above Antarctica, where the Sun's harmful ultraviolet (UV) rays bust through an otherwise sunscreened stratosphere, has shrunk to its smallest size on record going back to 1982, scientists have found.

Typically, at this time of year the hole in the ozone – a layer made up of molecules containing three oxygen atoms – grows to about 20 million square kilometres, NASA said. That's a gap bigger than Russia.

But unusually warm weather in the southern hemisphere means that the hole only extended less than 10 million square kilometres for most of September until now, according to a statement from NASA.

During the winter months in the southern hemisphere, clouds form in the stratosphere. There, even the smallest amount of visible light from the Sun breaks apart chlorine gas into chlorine atoms, which are considered 'reactive' and can chemically destroy ozone molecules. When temperatures over Antarctica start to warm up, the polar clouds in the stratosphere dissipate, meaning that there's no place for those ozone-annihilating chemical reactions to take place. This year, exceptionally warm weather put a halt to ozone-smashing, keeping that ozone hole small.

If higher temperatures are good for the ozone layer, does that mean the hole will get even smaller as humans pump greenhouse gases like carbon dioxide into the atmosphere? Not quite, says Paul Newman, chief scientist for Earth Sciences at NASA's Goddard Space Flight Center. It turns out carbon dioxide has the opposite effect in the stratosphere as it does in the layer closer to the ground called the troposphere. The CO_2 in the stratosphere absorbs and then emits that heat out into space, Newman explained, adding that this layer of the atmosphere is actually cooling off.

HISTORY

Three felines found in cat mummy

Words by **Yasemin Saplakoglu**

Scans of an ancient cat mummy revealed that the 2,500-year-old feline that was supposedly resting within the wrappings wasn't a single animal. Instead, the mummy held the partial remains of three cats, according to new findings.

A group of researchers recently analysed the 2,500-year-old Egyptian cat mummy that was part of a collection at the Museum of Fine Arts of Rennes, France. The scientists performed a computerised tomography (CT) scan, a type of X-ray, to illuminate what was inside the mummy without unwrapping it, and then they created 3D digital and transparent 3D-printed reconstructions of the mummy.

The scans revealed that this ancient mummy was filled with some surprises. Instead of the cat's head, the mummy held a ball of fabric. It was also missing a skull, vertebrae and ribs, and instead held five hind leg bones from three different cats. The bones were decomposed and riddled with holes created by corpse-eating insects, said Théophane Nicolas, a researcher at the National Institute of Preventive Archaeological Research who was part of the project. It's unclear why the Rennes cat mummy held the partial remains of three different cats, but some researchers believe that it was part of an "ancient scam organised by unscrupulous priests," Nicolas said in the statement.

Researchers used a CT scan to examine the insides of this ancient Egyptian cat mummy

© Museum of Fine Arts of Rennes

A Paris zoo is showcasing a brainless slime mould that acts like an animal

ANIMALS

Paris zoo obtains hungry 'blob'

Words by Brandon Specktor

The Paris Zoological Park in France has added a brand-new blob to its collection. No, it's not a jellyfish. It's not even an animal, really – more like a living pile of old yellow silly string that has a powerful hunger for fungus.

As you can imagine, scientists have had a hard time classifying such an organism. It looks like a fungus yet moves like an animal. It has no brain, yet it is capable of 'learning' to navigate complex mazes in a few hours on its curious quest for food. So just what exactly is this thing?

Technically, it's called a slime mould (*Physarum polycephalum*) – a single-celled organism capable of growing metres in size, though most specimens don't grow beyond a few square centimetres. They're found all over the world, usually on the undersides of leaves and logs, where they like to hunt fungi and bacteria. In the lab, however, the moulds have a hunger for porridge, and that has enabled researchers to unlock the slime mould's weird growth potential.

To capture food, slime moulds stretch out long veins of goo that can squiggle around obstacles or through mazes with surprising efficiency. In one 2010 study, scientists laid out dollops of porridge in a pattern representing Tokyo and the 36 surrounding towns. When let loose to feed, the slime mould branched out in a network similar to Tokyo's existing train system, connecting the food piles with impressive efficiency.

But wait, it gets weirder. Other studies have shown that slime moulds can actually follow their own slime trails back to a food source for subsequent feedings, suggesting that this brainless organism has a sort of spatial memory and problem-solving prowess. When two or more slime moulds merge together, they can share what they've learned and continue finding the most efficient path to food. Occasionally, hundreds of individual slime moulds can combine into a giant 'plasmodium', making decisions through a sort of hive mind.

It's no exaggeration when Paris Museum of Natural History director Bruno David calls slime moulds "one of nature's mysteries." You can see the mystery for yourself now at the Paris Zoological Park.

IN ASSOCIATION WITH LIVESCIENCE

PLANET EARTH

World's fastest-thinning glacier identified

Words by **Stephanie Pappas**

A glacier in Patagonia that has lost half its length in 30 years may be the fastest-thinning glacier on the planet.

Known as Hielo Patagónico Sur 12 (HPS-12 or Southern Patagonia Icefield), this huge mass of slow-moving ice is perched in the Andes mountains in Chile. Researchers reporting in the journal *Nature Geoscience* in September found that HPS-12 has been losing thickness and retreating inland. According to their analysis of satellite data, the glacier lost 30 metres of ice thickness each year on average between 2000 and 2008, near its terminal end. At its fastest, the thinning occurred at a rate of 44 metres per year, according to study co-author Etienne Berthier, a glaciologist at the University of Toulouse in France. The section where that thinning was recorded melted away entirely in 2018.

The Earth Observatory has released before-and-after photos showing the ice loss. One satellite shot – taken on 27 January 1985 by the Landsat 5 satellite – shows the ice of the glacier sweeping down from the mountains in the Southern Patagonia Icefield. A comparison shot taken by the Operational Land Imager on the Landsat 8 satellite in January 2019 shows a different world: the glacier hunkers into just a portion of its fjord, exposing bare rock.

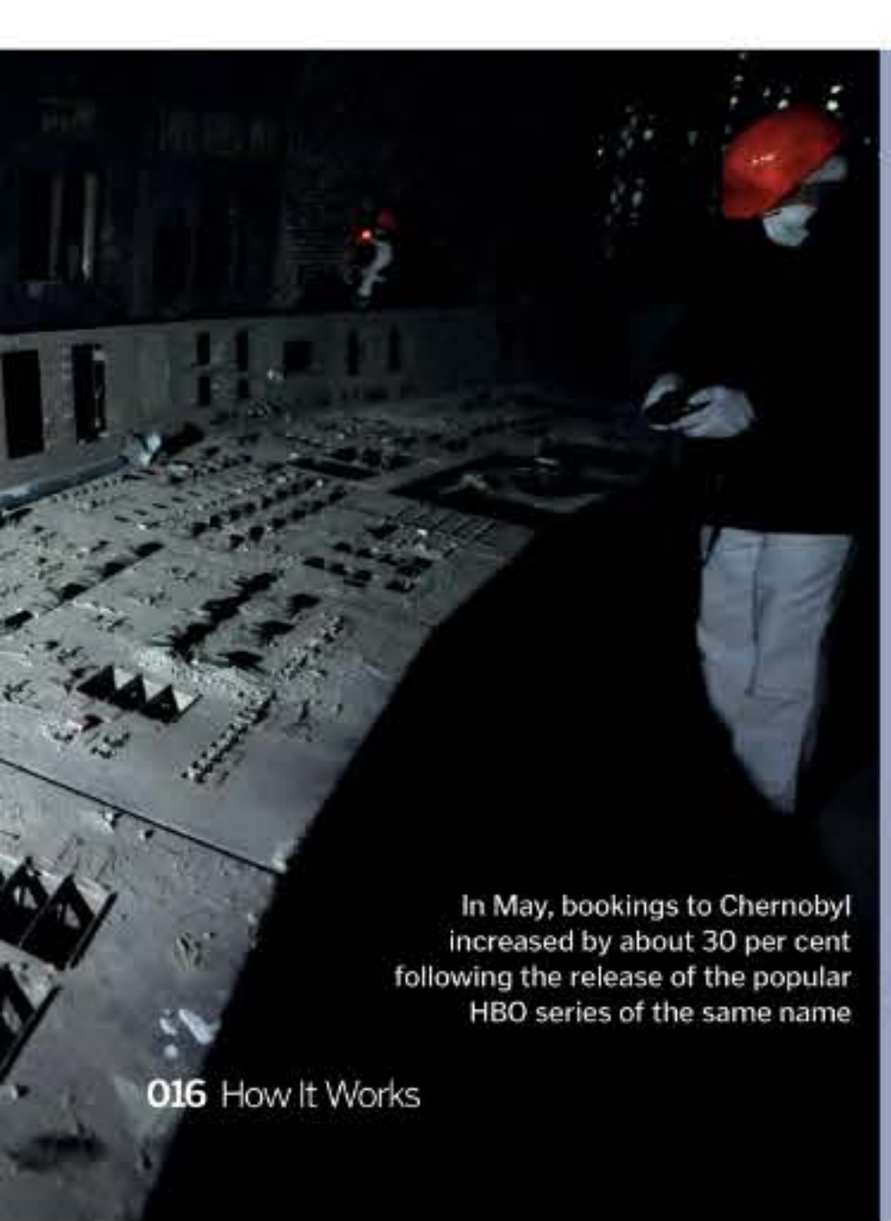
The glaciers of Peru and Chile are known as 'tropical glaciers', a seeming oxymoron that signifies that the glaciers sit in Earth's midsection, rather than near the poles. Tropical glaciers are retreating rapidly. Research released in 2013 found that glaciers in the Andes have lost between 30 per cent and 50 per cent of their surface area since the 1970s. These glaciers are vulnerable to warming both from above (due to air temperatures) and below (due to ocean temperatures at the glacier terminus, or the end of the glacier that is advancing or retreating).

© NASA Earth Observatory/USGS

A satellite view of the Hielo Patagónico Sur 12 (HPS-12) glacier as seen on 9 January 2019

A satellite view of the Hielo Patagónico Sur 12 (HPS-12) glacier as seen on 27 January 1985

© NASA Earth Observatory/USGS



In May, bookings to Chernobyl increased by about 30 per cent following the release of the popular HBO series of the same name

© Getty

STRANGE NEWS

Chernobyl's radioactive control room opens for tours

Words by **Yasemin Saplakoglu**

Tourists can now visit the control room of Chernobyl's Reactor 4, the scene of one of the world's worst nuclear disasters. But the control room is still highly radioactive, and visitors are required to wear protective gear when inside, according to recent news reports.

Ukrainian President Volodymyr Zelensky declared Chernobyl an official tourist attraction in June at the inauguration of a gigantic dome built to contain radioactive material.

Previously, Reactor 4 had remained closed off to most of the public, except for a few researchers and cleanup workers. Now, Chernobyl tour companies have confirmed that the control room is open to the brave souls who wish to be closer to the scene of the disaster, according to *CNN*.

The radiation in the room is 40,000 times higher than normal levels, according to *Ruptly*, a German news agency. Anyone who wishes to visit the site must wear a protective suit, a helmet and a mask, and limit their visit to just five minutes. Afterwards, visitors are required to undergo two radiology tests to measure the amount of radiation they were exposed to, according to *CNN*.

SPACE

Hubble photographs colliding galaxies

Words by **Hanneke Weitering**

Glowing eyes from a ghastly face glowers in deep space in a new image from the Hubble Space Telescope. The piercing 'eyes' of this creepy space face are the bright cores of two distant galaxies in the middle of a head-on collision, and they're surrounded by a mishmash of stars from their respective galactic discs. A ring of young blue stars contours the shape of the eerie face, while dense clumps of stars have come together to form its nose and mouth.

But this spooky mug won't be staring off into space forever. The ring structure that outlines the face will last for only about 100 million years, while the merging of the two galaxies is expected to take about 1 billion to 2 billion years, NASA officials said in a statement.

While galaxy collisions are quite common in the universe, head-on collisions like this one are relatively rare, and the particularly violent nature of this type of collision gives rise to the peculiar ring shape. "The galaxies have to collide at just the right orientation to create the ring," NASA officials said. "The crash pulled and stretched the galaxies' discs of gas, dust and stars outward. This action formed the ring of intense star formation that shapes the nose and face."

But that rare galactic ring isn't the only thing that makes this pair of merging galaxies special. While most galaxy collisions involve a larger galaxy gobbling up a smaller neighbour – even our own Milky Way galaxy is guilty of galactic cannibalism – the two galaxies merging here appear to be roughly the same size. In other words, there aren't many pairs of symmetric 'eyeballs' ogling through the cosmos.

This galaxy merger is known as Arp-Madore 2026-424, a designation that combines the names of the two astronomers that described it in their book *A Catalogue of Southern Peculiar Galaxies and Associations*, Halton Arp and Barry Madore. Arp-Madore 2026-424 is about 704 million light years away from Earth, located in the constellation Microscopium.

Hubble scientists captured this image on 19 June as part of a 'snapshot' program that's investigating unusual interacting galaxies. These observations will help NASA choose targets for its James Webb Space Telescope, Hubble's successor, which is scheduled to launch in 2021.

The Hubble Space Telescope's Advanced Camera for Surveys captured this image of two merging galaxies, collectively known as Arp-Madore 2026-42

IN ASSOCIATION WITH LIVESCIENCE

HEALTH

Tapeworm found in man's brain

Words by Rachael Rettner

Although Spirometra tapeworms occur worldwide, most human cases have been reported in Southeast Asian countries

A man in China experienced seizures and other mysterious symptoms for years before doctors finally found the cause – he had a rare parasite living in his brain, which had likely been there for more than a decade, according to news reports.

The man, who lives in Guangzhou, China, said that he began to feel numbness on the left side of his body starting in 2007, according to *Fox News*. In the following years, he developed more worrying symptoms, including blackouts and seizures, although doctors failed to find the true cause of his illness.

Then, in 2018, doctors discovered a nearly 12-centimetre-long tapeworm in his brain. He was diagnosed with sparganosis, an infection caused by a type of tapeworm larvae that's known as Spirometra.

Humans are rarely infected with Spirometra, because the parasite typically lives in the intestines of dogs and cats, according to the Centers for Disease Control and Prevention (CDC). However, humans can sometimes become infected if they drink water that's been contaminated with the parasite, or if they eat undercooked meat from animals such as frogs or snakes that are hosts to the parasite. The parasite can live for up to 20 years in humans, the CDC says.

Doctors removed the tapeworm from the man's brain during a two-hour surgery. "The surgery was risky," Dr Gu Youming, the man's surgeon, told *AsiaWire*, according to *Fox News*. "The live tapeworm was moving in his brain, and we had to remove all of it, otherwise the leftover part could grow again."

SPACE

Curiosity rover's eerie martian mountain photo

Words by Brandon Specktor

Mars is the only known planet in the universe inhabited solely by robots. There's InSight, the sturdy robo-stethoscope listening for the Red Planet's heartbeat; there's Odyssey and the gang, a cadre of droids surveilling the planet from orbit. And then, climbing a lonely crater hundreds of kilometres away from its companions, there's Curiosity, the last surviving rover on Mars.

Capable of travelling 30 metres per hour, Curiosity has been exploring the 3.5-billion-year-old pit called Gale Crater since landing there in 2012. Now, Curiosity is climbing the mountain, known as Mount Sharp or Aeolis Mons, at the crater's centre. In a bleak and beautiful photo taken on the 2,573rd Martian day of Curiosity's mission (1 November), the rover showed off the vast emptiness of this rocky domain.

In the new picture, posted to NASA's Mars mission website, a debris-strewn butte curves up towards the mountain's side, while an enormous ridge of hazy rock looms in the background. That ridge is actually the rim of Gale Crater, fencing the rover in for about 80 kilometres in every direction.

The photo was taken from Curiosity's back, showing the bleak horizon that the rover leaves behind as it begins its slow ascent from Mount Sharp's base. It's a lonely scene, to be sure, but Curiosity is looking for new friends all the time; one of the rover's primary objectives is finding evidence that Mars could (or once did) support microbial life.

© NASA/JPL-Caltec

The Curiosity rover is looking for life on Mars, but it's looking bleak

© Creswell Crags Museum and Heritage Centre

These marks were used as protection against evil spirits and witches

HISTORY

Cave 'witch marks' get digital makeover

Words by **Mindy Weisberger**

Mysterious 'witch marks' that were carved into a cavern's walls centuries ago to ward off evil are getting a public viewing, thanks to 3D modelling and animation.

The marks were discovered earlier this year in Creswell Crags, an enclosed limestone gorge in the UK. Further investigation revealed hundreds of carved emblems such as these were common in the medieval UK, etched around doorways, windows and fireplaces to keep evil spirits out.

Site officials partnered with researchers at Sheffield Hallam University in South Yorkshire, England, to scan the marks and create a virtual tour of the remarkable sight.

University researchers scanned the marks with a technology called lidar – light detection and ranging – which creates maps by pinging a surface with lasers and then measuring the reflected light. Photogrammetry will map the surfaces in 3D, creating a virtual cave that will make the marks accessible to the public and to scientists; the team recently produced an animated preview of the virtual tour, sharing the footage on Vimeo.

The witch marks were inscribed into the cave walls between the 16th and 19th centuries, likely by generations of local people who added to the existing marks over time. However, it's unknown what motivated them to apply so many layers of protective wards on the cave walls and ceilings. It's possible that they were created during times of crop failure or disease outbreaks, and people may have also viewed the caves as a passageway for evil spirits to reach the surface from a subterranean hellscape below, said Duncan Wilson, a chief executive at Historic England.

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WISH LIST

Christmas gift guide

ANAFI

Take stunning high definition 4K images from the skies with Parrot's ANAFI drone. This robust, weather-resistant drone boasts a flight time of around 25 minutes to capture the best moments of any adventure. ANAFI is the first drone to be equipped with a 180-degree tilt gimbal, allowing you to capture a range of images from both above and below.

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The Force™ Coding Kit

Awaken the force with this coding kit from Kano. Using the Kano Star Wars sensor, swing lightsabers, levitate X-wings and pilot starships with a wave of your hand. With Kano's simple building block programme, quickly become a coding master and send stormtroopers flying, or lift R2-D2 off the ground and create your own *Stars Wars* adventure.

Price:
£79.99 / $79.99
www.kano.me/uk

Price:
From £199 / $199
www.oculus.com

Oculus Go

Entering the realm of virtual reality is made easy with all-in-one Oculus Go. As a standalone device, the Oculus Go doesn't need to pair with your computer or games console. Using the wireless control, scroll through your favourite shows on Netflix or play one of the many pre-installed games and apps. Portable and easy to use, this VR headset offers crystal-clear visuals and cinematic sound.

© Hornby Hobbies

Price:
From £12.99 / $16.99
www.airfix.com/quickbuild

Airfix QUICK BUILD Lamborghini Aventador

Always dreamed of owning a Lamborghini? Airfix QUICK BUILD is an exciting range of simple, snap-together models suitable as an introduction to modelling for kids, or as a bit of construction fun for any Lamborghini lover. There is no paint or glue involved, so the model can be dismantled and rebuilt as many times as you like, or else you may choose to put your masterpiece on display. There are a wide range of QUICK BUILD models available, including aircraft, tanks, super cars and iconic VWs, all of which are compatible with other building-block brands.

© Acton

Price:
$449 (approx $350)
www.actonglobal.com

Blink S-R

Zip across campus or sail along the coastline with the ACTON Blink S-R electric skateboard. Reaching a top speed of 15 miles per hour, this wirelessly controlled skateboard will get you from A to B in no time. The Blink S-R has a range of around 11 kilometres (seven miles), and with the board's built-in lights, riders can travel at night safely.

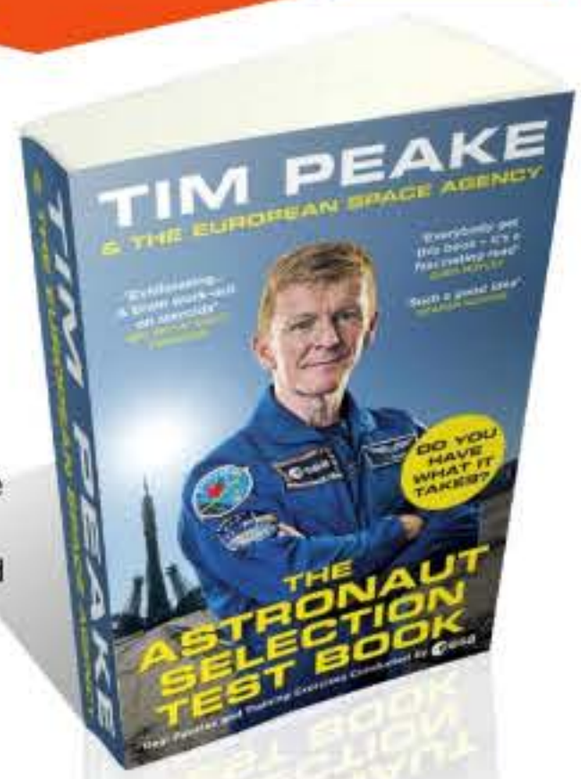
www.howitworksdaily.com

Christmas READING LIST

The Astronaut Selection Test Book

- Author: **Tim Peake and the ESA**
- Publisher: **Century**
- Price: **£12.99 (approx $15)**

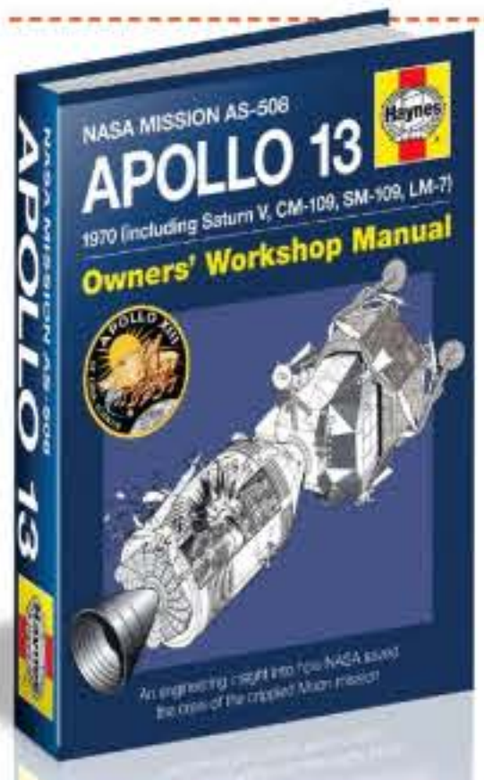
Have you got what it takes to become an astronaut? Explore the 100 real astronaut tests and exercises from The European Space Agency (ESA) selection process to find out. From visual perception and mental arithmetic to psychological readiness, this book is jam-packed with fun puzzles and tests to get you ready to jet off into space.



Haynes Practical Lifestyle Manuals

- Author: **Various**
- Publisher: **Haynes**
- Price: **from £6.99 to £25 (approx $10 to $30)**

Whether you're looking for a main present or a stocking filler, Haynes has Christmas wrapped up. Haynes' books cover a vast array of topics, from racing cars to samurai warriors, and bee hotels through to WW2 tanks, plus the hilarious parody range of Haynes Explains titles and a selection of fun new kid-friendly Pocket Manuals.



Sean Yeager Adventures

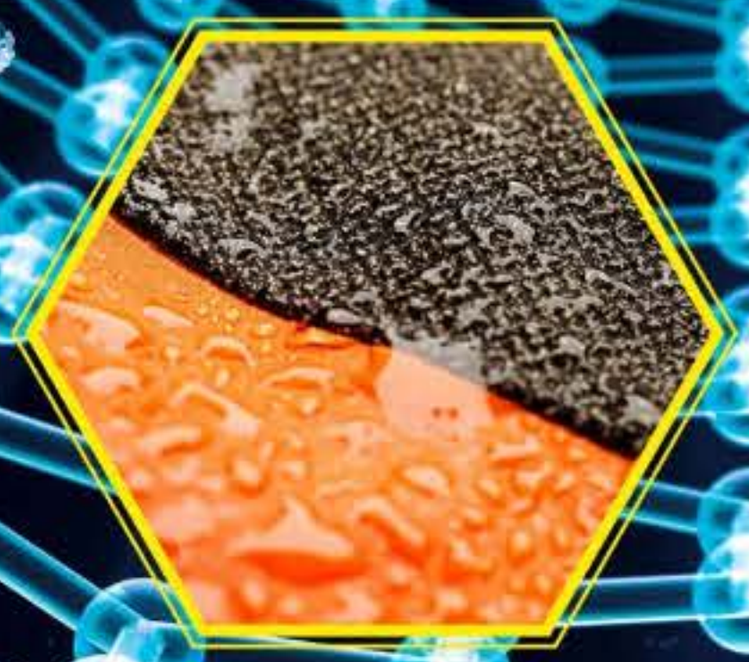
- Author: **D.M Jarrett**
- Publisher: **Aenathen Omega**
- Price: **£7.99 (paperback)**

Enjoy the magic of Sean Yeager Adventures this Christmas. Treat your youngsters to a world full of surprises, where secret agents and robots run amok, and high-tech gizmos abound. Follow Sean and Emily as they evade their arch-enemy and search for clues about their missing fathers. Can they find a way to save humanity from an ancient and deadly threat?

SUPER SUBSTANCES

DISCOVER TEN OF THE WORLD'S STRANGEST AND MOST AWESOME NATURAL AND MAN-MADE SUBSTANCES

Words by **Andy Extance**



All substances are built up from the same set of 118 elements, so how is it possible that they can be so different? Some elements are interesting in themselves, like gallium, which melts in people's hands, or the powerful nuclear fuel plutonium-238. The atoms of more ordinary elements, like carbon and hydrogen, make up the everyday objects around us. Atoms linked together as molecules even make up our own bodies. Often, carbon atoms are linked together in long chains to create the plastics that we both love and hate. But in some molecular arrangements, carbon can become rather extraordinary.

Organised in flat sheets as graphene and made into an aerogel, carbon becomes the lightest material on record. Carbon also makes the darkest material ever, called Vantablack, in the form of nanotubes that are effectively rolled-up graphene sheets. Or, when combined with hydrogen and fluorine in chains, carbon is part of waterproof textiles that keep us dry.

Mixtures of atoms and molecules, or just mixes of different molecules, can be just as awesome. Ferrofluids combine iron, water and other more complex molecules to give uniquely spiky shapes.

Sometimes the properties that a particular arrangement of atoms provides are useful, sometimes they're dangerous. They can often be entertaining or just flat-out amazing. Sometimes they're all of these at once.

So how is this variety possible? The answers that physics and chemistry offer can be deep – but often they are simple. And understanding them brings more than a moment's pleasure. It also provides us with starting points for new ideas to make the world a better place.

In the 1970s, plutonium-238 was used to power pacemakers to keep people's hearts beating

Ferrofluids were first developed by NASA as a way to move fuel in space

MAGNETIC LIQUID

Metallic droplets that make intricate shapes

DANGER ●●○○○ **USEFULNESS** ●●●○○

Iron is common – it's why your blood tastes metallic. So you might be surprised to know that it also helps to form hedgehog-shaped droplets.

To make these spiky 'ferrofluids', people mix tiny iron particles into a liquid with molecules called surfactants – which is what gives washing-up liquid its cleaning power. The surfactants stop the iron clumping together.

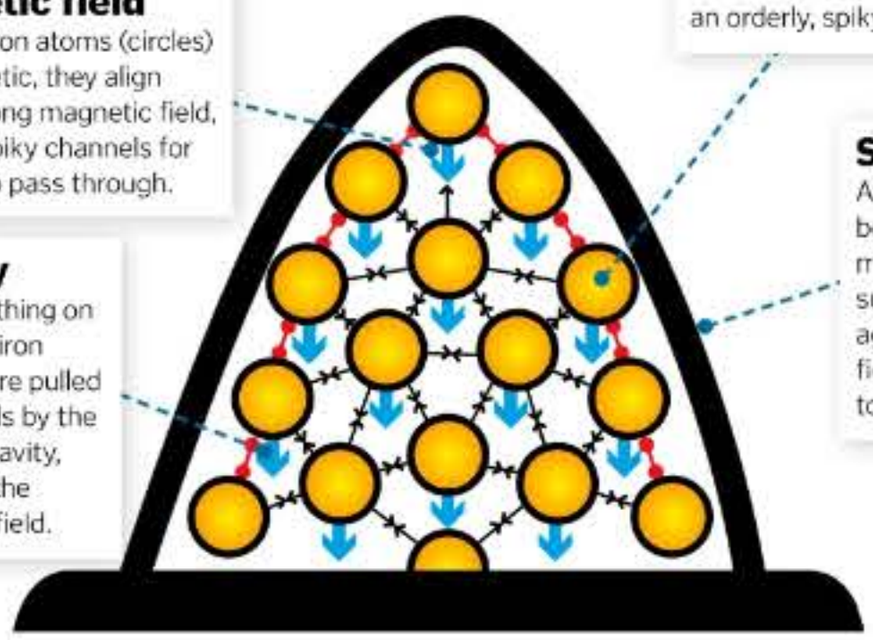
When you put a drop of the liquid near a magnet, the magnet moves tiny iron particles along magnetic force lines with gaps between, like you see with dry iron filings. However, in liquids the molecules gently attract each other. When they meet the air, this creates a force known as surface tension. Surface tension and gravity pull against the magnetic forces, keeping the iron particles in the droplet. Spikes form because ferrofluids channel magnetic force lines, and troughs form in between. Such ferrofluids can be used in electronics and engineering, in products containing magnets, such as speakers.

How ferrofluids spike

Forces wrestle each other and find balance in unique forms

Magnetic field
Because iron atoms (circles) are magnetic, they align with a strong magnetic field, forming spiky channels for the field to pass through.

Gravity
Like everything on Earth, the iron particles are pulled downwards by the force of gravity, opposing the magnetic field.



Interatomic forces
As the iron atoms align with the magnetic field, they become magnetised themselves, and arrange into an orderly, spiky structure.

Surface tension
Attractive forces between liquid molecules create surface tension, pulling against the magnetic field to bring iron atoms together in spikes.

SELF-HEATING METAL

This element is the ultimate power source for space missions

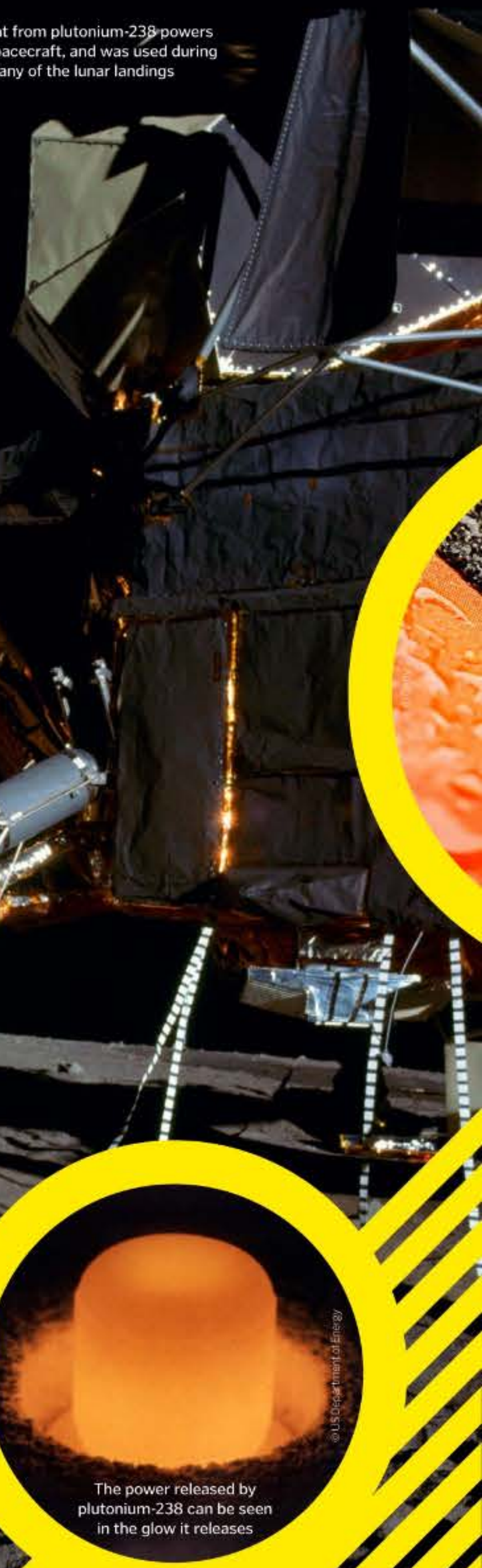
DANGER ●●●●● USEFULNESS ●●○○○

Plutonium is sometimes called the 'most toxic substance known to man' – but it is also a hugely powerful nuclear energy source. A ten-centimetre-diameter plutonium sphere weighing eight kilograms can produce an explosion as big as the bomb that hit Nagasaki in 1945.

Plutonium forms different isotopes, where its atoms have the same number of protons but a different numbers of neutrons. Making it involves bombarding an isotope of the rare radioactive element neptunium with neutrons in a nuclear reactor.

As with all radioactive elements, plutonium-238 slowly decays to lighter elements. Plutonium-238, with 94 protons and 144 neutrons, generates enormous amounts of heat as it decays into uranium-234, with 92 protons and 142 neutrons. Some spacecraft are powered with that heat, like Voyager 1 and 2, which visited planets in the Solar System. Some old pacemakers were powered the same way, but we now keep hearts going with less hazardous batteries.

The heat from plutonium-238 powers many spacecraft, and was used during many of the lunar landings



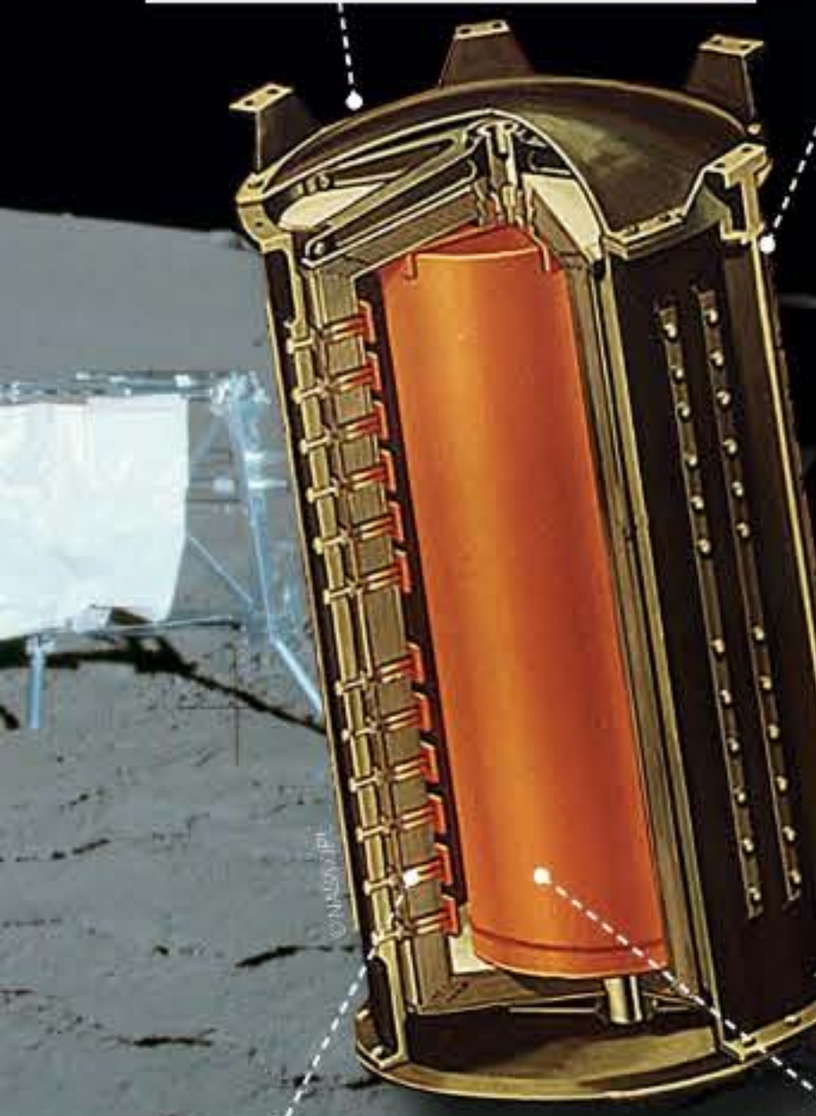
© NASA

Plutonium-238-powered voyages

The Voyager probes explored our Solar System's outer planets, helped by radioisotope thermoelectric generators (RTGs)

Radiation shielding
To protect the Voyager probe's other components from radiation damage, the RTG needs to be shielded with materials like beryllium.

Eight laptops' worth of power
At first, the RTG produced 157W of electrical power, which halves every 88 years. An efficient modern laptop consumes around 20W.



© NASA/JPL

Silicon-germanium thermocouple
The heat source is surrounded by a thermocouple device made of silicon germanium, which converts heat to electricity.

Plutonium-238 heat source
Spheres of plutonium-238 dioxide in the centre of the RTG give off heat to power the Voyager spacecraft.

© U.S Department of Energy

The power released by plutonium-238 can be seen in the glow it releases

SUPER-WATER REPELLANT TEXTILE

Technology that keeps us dry

DANGER ●●○○○ **USEFULNESS** ●●●●●

The same coatings used to make some fabrics water repellent can also make non-stick cooking pans. Both use polytetrafluoroethylene (PTFE), which consists of long chains of carbon, hydrogen and fluorine atoms, and is sometimes called Teflon. PTFE is slippery because other atoms struggle to stick to fluorine, so water easily rolls off.

Heating and stretching PTFE threads to eight times their original length transforms them into waterproof materials like Gore-Tex.

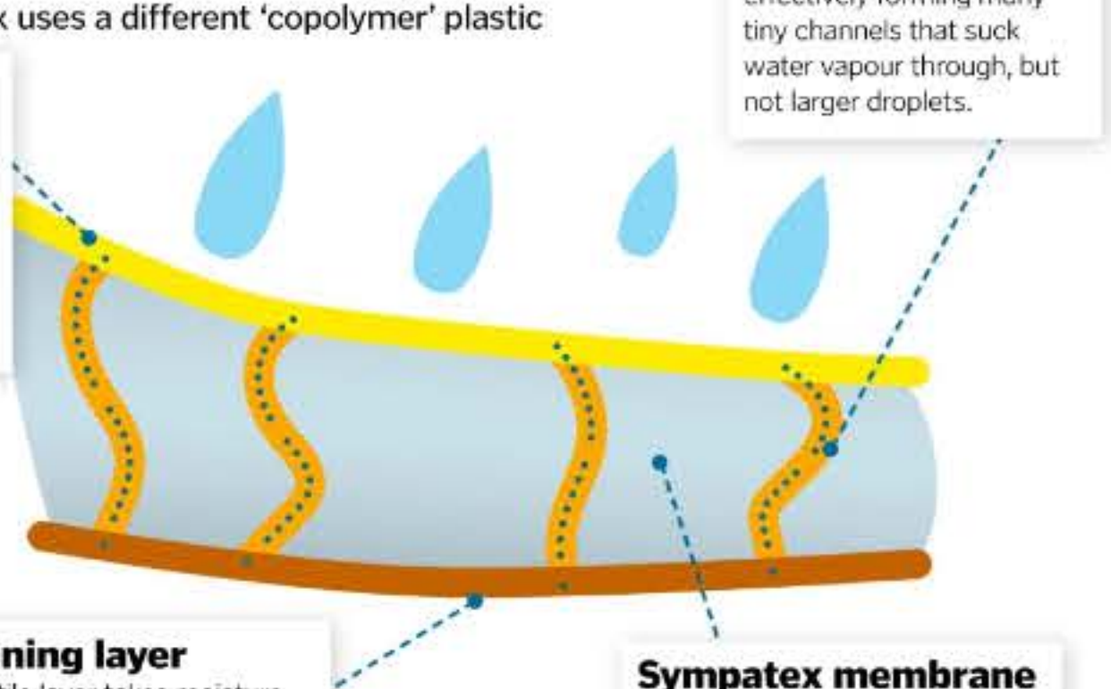
Air makes up around 70 per cent of these materials, leaving small holes that run through it. Alone, water molecules from our bodies are small enough to pass out through them. But lots of water molecules together make droplets about 20,000 times bigger than these holes and can't get inside.

Even more waterproof 'superhydrophobic' coatings emulate lotus flower petals. These petals have rough surfaces, trapping air underneath water droplets. Water droplets are therefore more likely to roll away. Roughening coatings like PTFE works in a similar way.

Water can't pass through the tiny holes in PTFE-based materials like Gore-Tex

Un-holey dryness

Unlike Gore-Tex's holey PTFE layer, hydrophobic textile Sympatex uses a different 'copolymer' plastic



© Surrey Nanosystems

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Vantablack absorbs so much light it doesn't produce reflections that normally help define shapes

VANTABLACK

The world's blackest material?

DANGER ●○○○○

USEFULNESS ●●●○○

Seeing Vantablack is more like looking at a hole into nothingness than something painted black. As one of the world's blackest materials, it absorbs 99.96 per cent of all visible light that hits it.

Doing this requires materials made of carbon, connected up into tiny cylinders called nanotubes. In the original Vantablack, they're created vertically on an aluminium foil. The nanotubes are aligned precisely, and under a microscope they look something like a densely packed brush. When light hits the surface, it's trapped inside and between the nanotubes. This stops reflections that could affect measurements, such as in super-sensitive telescopes.

But Vantablack is no longer the very blackest material. Recent research from MIT has produced a rival, with a random organisation of nanotubes that absorbs 99.99 per cent of light.

HOT ICE

Sodium acetate stores and releases heat

DANGER ●○○○○ **USEFULNESS** ●●○○○

How can ice be hot? Well, it's not actually ice, as in frozen water. It's a chemical called sodium acetate, which goes from liquid to solid a bit like ice, releasing heat. Heating pads and hand warmers therefore use it.

Some sodium acetate crystals contain water, which helps to store and release energy. When energy is put in as heat, the crystals melt. The sodium acetate then dissolves in the water contained in the crystals. The mixture remains as a liquid when it cools down, but can easily turn back into a solid. All it takes is a little extra push, like when someone presses on a metal disc in a heating pad. Then the liquid crystallises back into solid sodium acetate, releasing heat energy.

© Alamy

Heat pads make use of sodium acetate

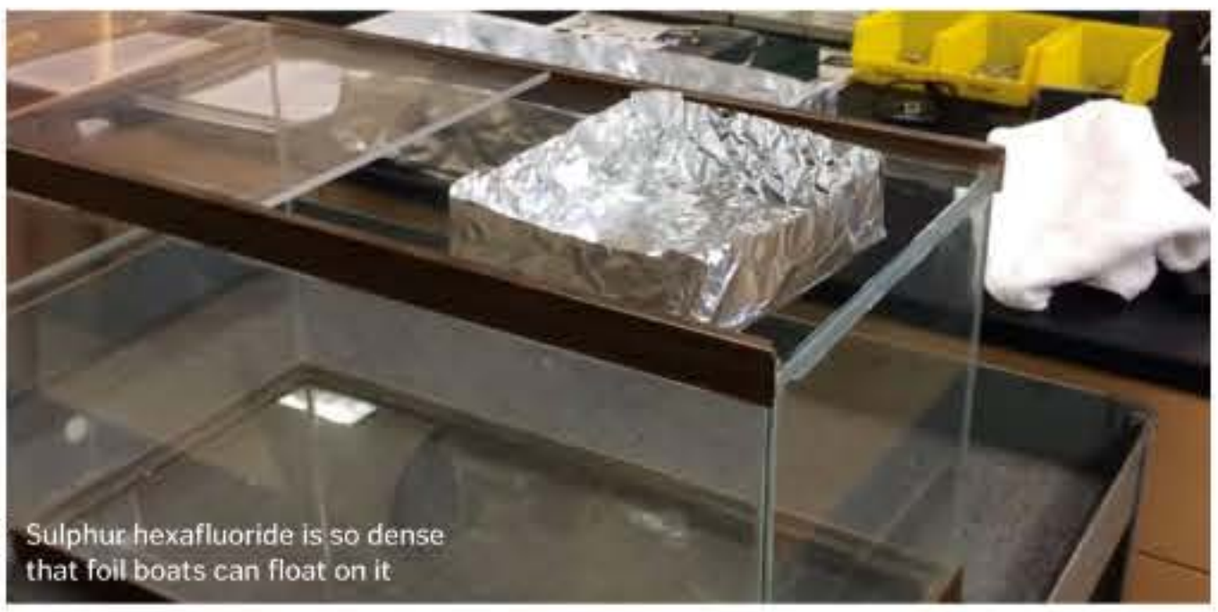
INDESTRUCTIBLE, HEAVYWEIGHT GAS

Brilliant for industry, bad for the environment

DANGER ●○○○○ **USEFULNESS** ●●●○○

Sulphur hexafluoride hardly ever reacts, which is both good and bad. Strong acids can't break it down, and it doesn't burn. The electricity and temperatures above 1,000 degrees Celsius used in magnesium smelting don't touch it either, which is useful. Magnesium is highly reactive so there is a strong fire risk, but sulphur hexafluoride gas can blanket the process safely.

That's because fluorine atoms surround the sulphur atom at the molecule's centre, protecting it from chemical attack. The same property stops sulphur hexafluoride molecules interacting with each other and forming a liquid or solid. Instead it's a very dense, invisible gas, which lightweight foil boats can even float on. However, it's also a very potent greenhouse gas – and the fact it's so stable is a problem for Earth's climate.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Sulphur hexafluoride is so dense that foil boats can float on it

GRAPHENE AEROGEL

So light, it floats on air

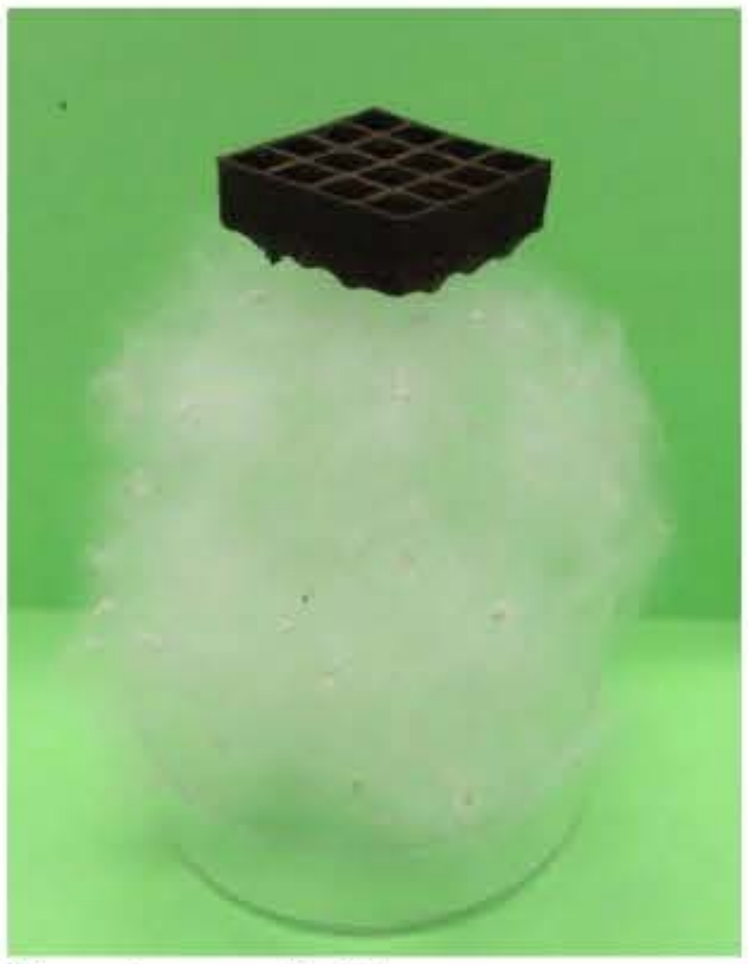
DANGER ●○○○○

USEFULNESS ●●●●○

When we buy balloons filled with helium, we can forget how rare and expensive this gas is. Luckily, carbon materials known as graphene-based aerogels might provide an alternative. Amazingly, they're the world's lightest material – almost one-eighth as dense as air. A cubic metre weighs just 160 grams, compared to 1,000 kilograms per cubic metre for water.

Graphene is single layers of carbon in its graphite form. Some types of graphene are left on paper when you write with a pencil. However, it's only recently that scientists have realised graphene has various exceptional properties, including strength. Whereas gels are mixtures of solids in liquid, aerogels refer to dispersions of solids in air. One way to make graphene aerogels is mixing graphene with water and 3D-printing it onto a -25-degree Celsius surface that freezes it. You can then remove the ice without melting it using a method called 'freeze drying'.

"The world's lightest material – almost one-eighth as dense as air"


© University at Buffalo

This graphene aerogel is light enough to sit on a ball of cotton

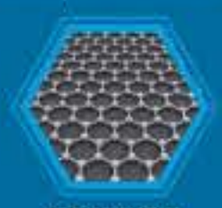
GRAPHENE GOES FLAT OUT

COMPOSITES | ENERGY | DATACOM | ELECTRONICS | SENSOR & IMAGING | BIOMEDICAL TECH

2020 TO 2022

Functional coating and surface modification
Graphene promises thin, advanced protective coatings.

FAST-CHARGING BATTERIES



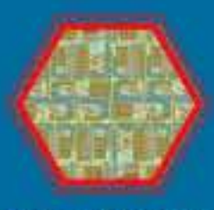
STRUCTURAL MATERIALS

ADVANCED SOLAR PANELS

MULTIFUNCTIONAL CONSTRUCTION MATERIALS

FLEXIBLE SOLAR CELLS

ADVANCED OPTICAL COMMUNICATIONS



Low-cost printable electronics
Conductive inks containing graphene can be printed to make cheap integrated circuits.

PHOTODETECTORS AND PHYSICAL CHEMICAL SENSORS

Broadband cameras and spectrometers
Graphene-enabled image sensors can detect many visible and invisible colours, while single-pixel graphene spectrometers can identify many materials. This has multiple applications – particularly space missions.

Biosensors
Graphene withstands our soggy insides better than most electronics, meaning it might bring better at monitoring of what's happening inside us.

2023 TO 2029

Water treatment and desalination
Graphene sheets can serve as a mesh that separates water molecules in seawater from salt's sodium and chloride ions.

SUPERCAPACITORS FOR WAREHOUSES

MULTIJUNCTION PHOTOVOLTAICS

Advanced network infrastructures
Graphene can be used to help produce lasers that can pulse quickly, which might help send internet data faster.

HIGH-FREQUENCY ELECTRONICS

Flexible devices
Graphene is highly conductive, thin and strong, making it ideal for use in lightweight and potentially flexible electronics.

Neural interfaces
Scientists should be able to implant thin and robust graphene electrodes into brains.

2030 & BEYOND

Fuel cells for vehicles
Fuel cells need membranes that let only protons through, and graphene has been shown to do this better than existing materials.

6G AND BEYOND WIRELESS NETWORKS

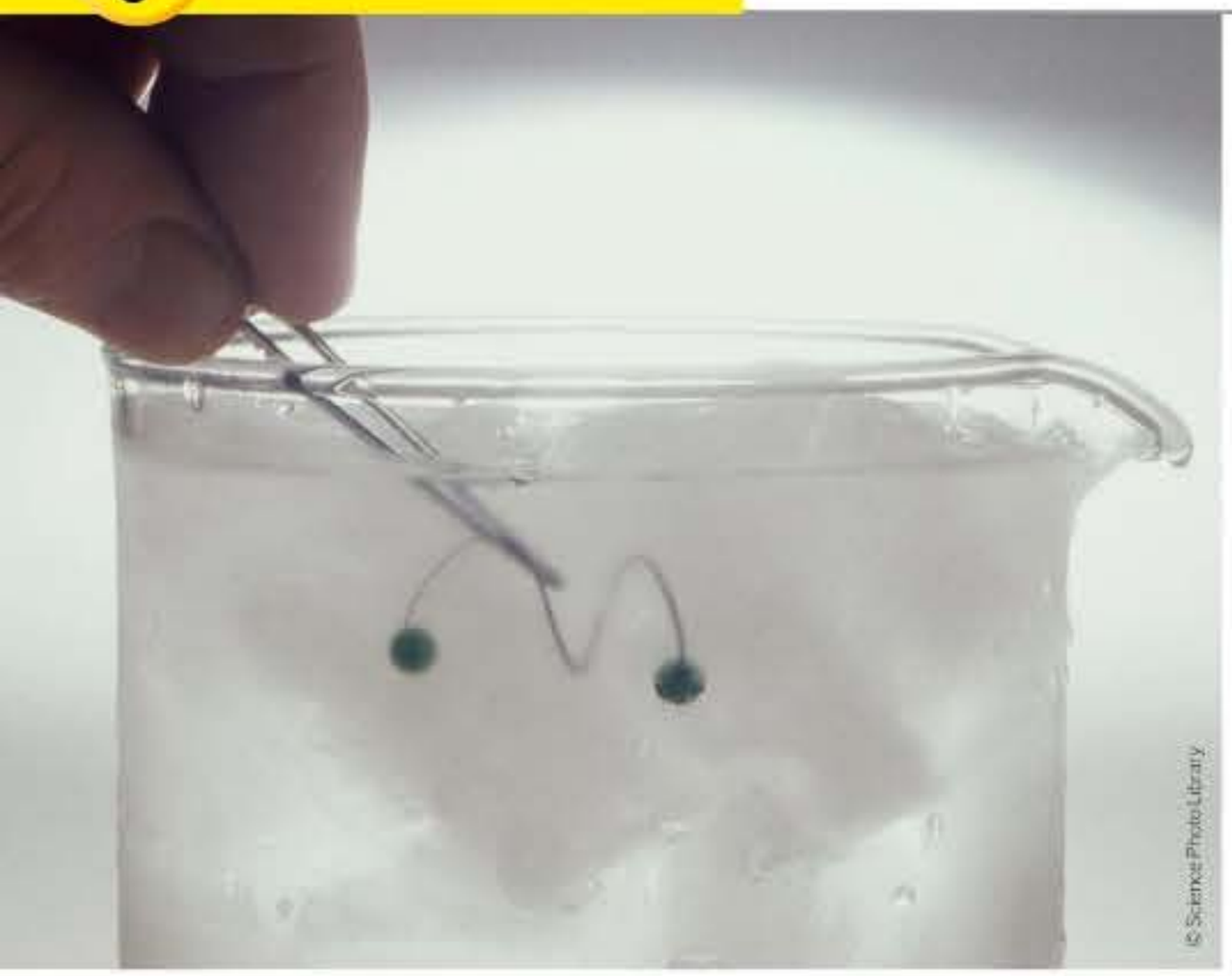
On-chip optical data
Graphene could produce components that might enable laser-based signals to replace electrical signals within electronic chips.

Spin logic devices
Low-power, low-volatility and high-speed electronics

Drug delivery
Drug molecules could sit on graphene sheets, which could carry them into our bodies and help protect them.

BIOELECTRIC IMPLANTS

Source: NASA; SciPort medical / Wiki; MSinkhorn; BCIT; Perez Partensky; Maido Mensaliu; Devbose; AlexanderAUS; Rosertyan; Pang Kakit Ken Ichi Nakazwa chaitawat Superdiddy; US Navy; Angelcelltrole; Anita Fors; Asumipal; CSIRO; Lucovi Hirlmann; Rogilbert commonswiki; Epop; Anders Sandberg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METAL THAT HAS A MEMORY

This clever alloy can shift its own shape

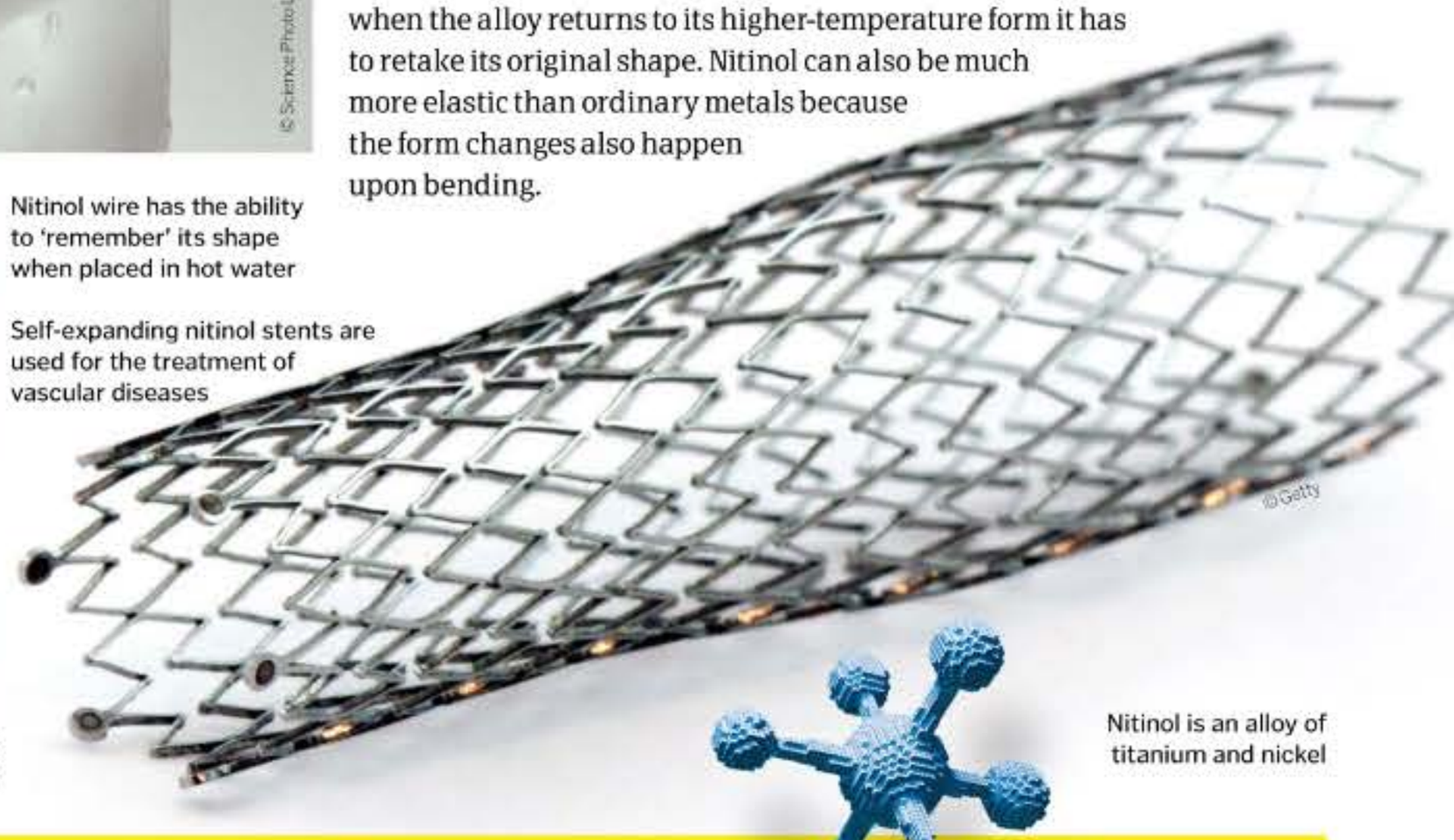
DANGER ●○○○○ **USEFULNESS** ●●●●○

Sometimes, a nitinol wire is straight and bendy like most other metals. Heat it up, however, and it can spring into a pre-imprinted shape. This 'shape memory' is helpful in medicine, for example as stents that keep blood vessels open. When cool, nitinol can be squashed and inserted by keyhole surgery. Once put in place, body temperature drives it back to its original size and shape.

The change comes because the nickel and titanium atoms in the alloy organise themselves in two ways at different temperatures. After cooling to the lower-temperature form it can be put into one shape, but when the alloy returns to its higher-temperature form it has to retake its original shape. Nitinol can also be much more elastic than ordinary metals because the form changes also happen upon bending.


© Getty

Nitinol wire has the ability to 'remember' its shape when placed in hot water


© Getty

Self-expanding nitinol stents are used for the treatment of vascular diseases

Nitinol is an alloy of titanium and nickel

TOUCH-SENSITIVE EXPLOSIVE

Nitorge Triiodide is extremely unstable

DANGER ●●●●● **USEFULNESS** ●○○○○

Apply the slightest pressure and nitrogen triiodide blows up. It's often made as a black powder that can be kept damp to stop it exploding unexpectedly. If you have more than a small sprinkling of it, you're in danger. But just a little smear can be fun in the hands of an expert.

When something touches dry nitrogen triiodide it quickly decomposes to form nitrogen gas, making a loud crack and purple smoke. The rapid expansion from solid to gas drives the explosion. It also expels iodine, the coloured gas.

Many such explosives are useful, but only if they're stabilised so they can't be set off by accident. However, nitrogen triiodide is hard to stabilise, meaning it's mainly used for entertainment.


© Science Photo Library

Nitrogen triiodide is hard to keep stable – any pressure when it's dry and it will explode

5 FACTS ABOUT MELTING METALS

1 Mercury -39°C
Often called quicksilver, liquid mercury was popular in scientific instruments such as thermometers, but as it's toxic it's less common today.

2 Copernicium Roughly 10°C
This synthetic metal decays to other elements within seconds, but it should be liquid at room temperature – if enough was ever made at one time.

3 Caesium 29°C
Like other metals in its periodic table group, caesium melts easily but also catches fire in air, so using it is rather difficult.

4 Indium 157°C
This soft element is important in electronics, forming transparent alloys that sit on the front of many electronic screens.

5 Bismuth 271°C
Bismuth melts readily to form beautiful, colourful spiral crystals and mixes with other metals to make easily shaped alloys.

Gallium's melting point is so low it can become liquid in your hand

© Alamy

GALLIUM MAGIC

It melts in your palm and lights up our lives

DANGER ●●○○○ USEFULNESS ●●●●●

If you've seen the disappearing spoon trick, you've probably heard of gallium. This metal is only just solid at room temperature, melting at 29.8 degrees Celsius. Holding it in the palm of your hand is enough to slowly melt it to a silvery puddle. Putting gallium in a cup of tea works even quicker.

That's because gallium doesn't form the standard high-stability metal structure, where all the atoms are held tightly together. Instead gallium forms clusters of just a few atoms, in structures that break down easily.

You might not have seen pure gallium, but you probably have gallium at home, combined with other elements. Gallium-based compound semiconductors are well-suited to turning electricity to light, and light into electricity. Gallium nitride is used to produce blue, green and white LEDs. Gallium arsenide is used to make red LEDs and solar cells used in space.

130 GIGAPASCALS
This tensile strength makes graphene the strongest material ever discovered

87.7 YEARS
The time it takes for half a plutonium-238 sample to decay

58°C
Sodium acetate's melting point lets hot water recharge 'hot ice'

BOB GORE DISCOVERED GORE-TEX BY ANGRILY YANKING ON PTFE THREAD

99.96%
Vantablack absorbs almost all the light that hits it

BOTH PLUTONIUM-238-POWERED VOYAGER PROBES HAVE LEFT OUR SOLAR SYSTEM

23,500
Sulphur hexafluoride harms the environment 23,500 times more than carbon dioxide

1973
Ferrofluids first helped remove heat from speakers in the 1970s

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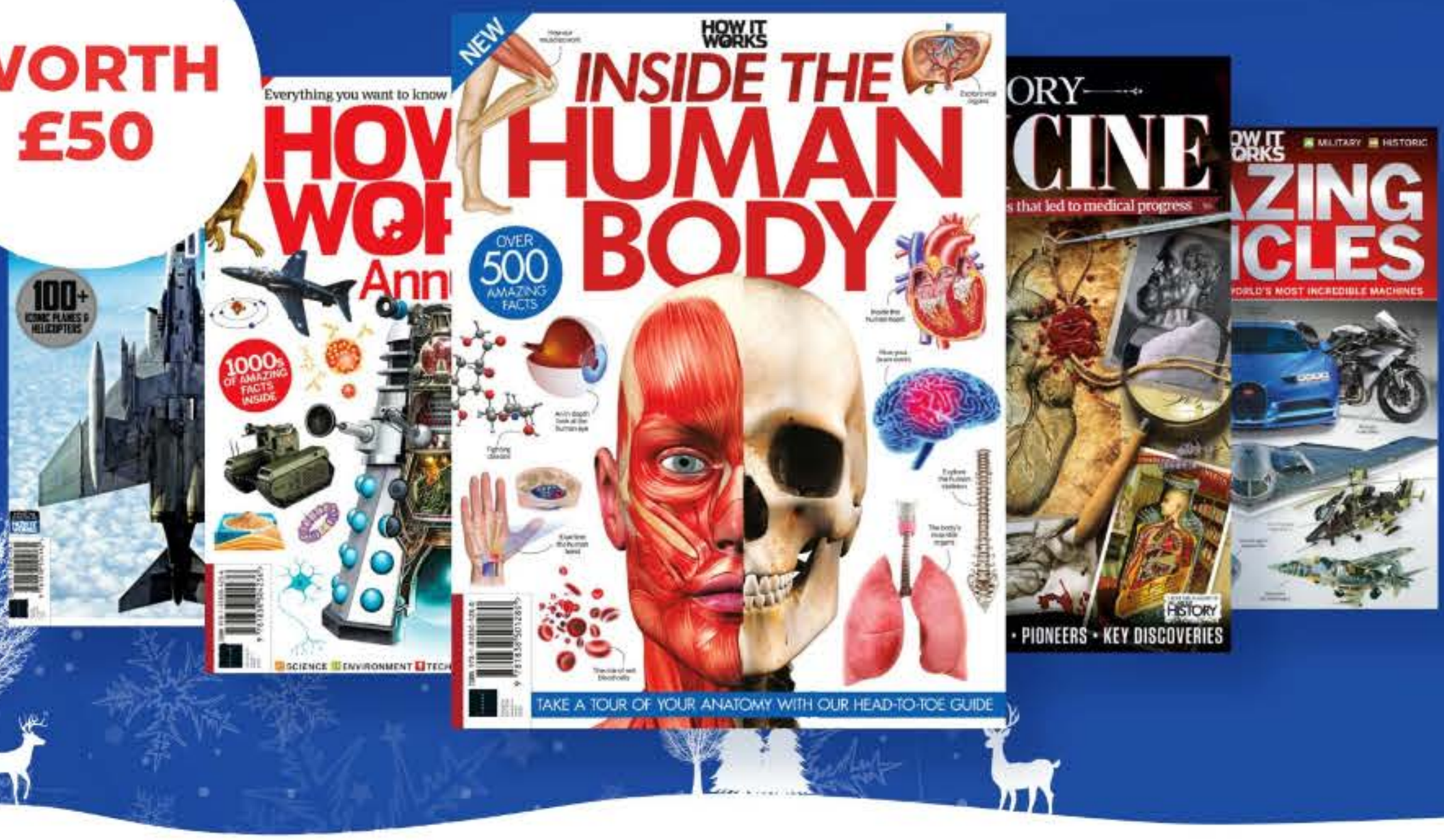

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How It Works Annual

Inside the Human Body

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DID YOU KNOW? *Theoretical physicist Paul Dirac was just 25 when he predicted the existence of antimatter in 1928*

MATTER VS ANTIMATTER

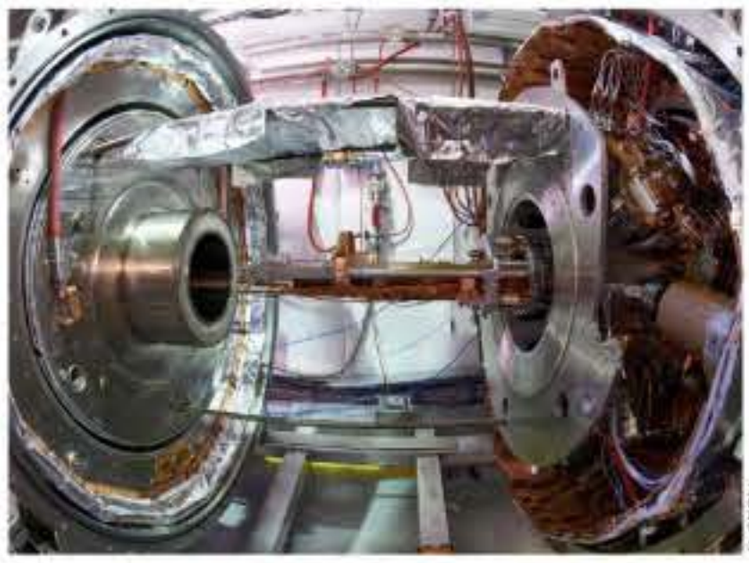
From space drives to bananas – everything you need to know about the mysteries of antimatter

Words by **Andrew May**

The very word 'antimatter' sounds like science fiction – on a par, perhaps, with antigravity. But antimatter is a perfectly real, well-established part of modern physics. It's true that it has some pretty dramatic possibilities, though. A gram of antimatter, if it came into contact with ordinary matter, would produce an explosion as big as a nuclear bomb. More usefully, because it's such an efficient source of energy, antimatter is the ideal candidate for future spacecraft propulsion. Surprisingly, however, there's nothing especially exotic about the nature of antimatter – it's a natural consequence of our current ideas about subatomic particles.

Most of the mass of an atom is contained in its nucleus, made of protons and neutrons. Orbiting around the nucleus are less massive particles called electrons. These are particularly important to us because of their role in electronics – each electron carries a negative electric charge (which is balanced by the positive charge on a proton). There are several other types of particle too, but they're usually only seen in high-energy physics experiments. All the particles that make up ordinary matter fall into two categories – 'baryons' like protons and neutrons, and 'leptons' like electrons.

This is starting to sound complicated, but it would get a lot more complicated if it wasn't for a



© CERN

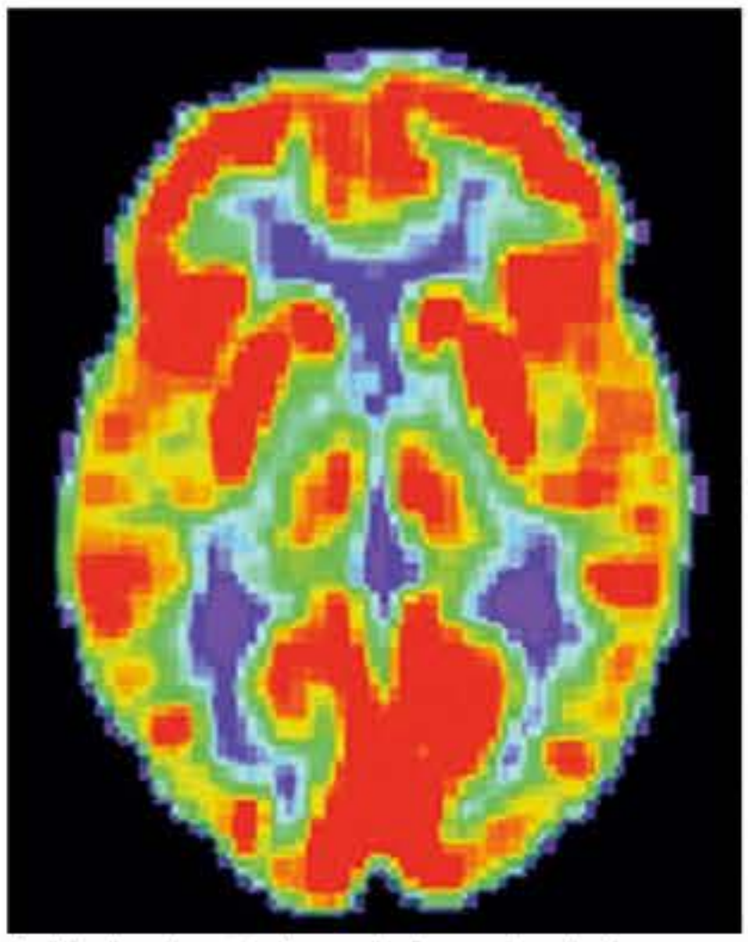
A magnetic 'trap' inside CERN's antimatter factory, capable of storing antihydrogen atoms

fundamental principle of nature called conservation laws. These bring order to what otherwise might be complete chaos. When particles interact with each other – for example in the high-energy accelerators at CERN – certain quantities are always conserved. Energy is one such quantity, and electric charge is another. It turns out that 'baryon number' and 'lepton number' are also conserved – and this is where we get onto the concept of antimatter.

A proton has a baryon number of +1 and a charge of +1. Theory also predicts its 'antiparticle' – with the same energy but a baryon number of -1 and charge of -1. It's called an antiproton. By the same logic, the electron also has an antiparticle – a positron – with positive electric charge and a lepton number of -1.

So what happens when, say, an antiproton meets a proton? You probably know the answer already, because it's the single best-known fact about antimatter. The positive and negative baryon numbers cancel out, as do the positive and negative electric charges and various other conserved quantities, until all that's left is the energy of the two particles. That's conserved too, but it's the only thing that's the same – not opposite – for both particles. So they disappear in a flash of energy – or more specifically, a gamma ray. That's an electromagnetic wave like light but with vastly greater energy, the same energy that just a moment ago was locked up inside the proton and antiproton. Called 'annihilation', it's the only process we know of that's capable of converting mass into energy with 100 per cent efficiency.

The reverse process is possible, too. Given enough energy, a particle-antiparticle pair can pop into existence from nowhere. With massive particles like protons and antiprotons, such pair production only takes place inside high-energy accelerators, or in exotic astrophysical processes. But the creation of electron-positron pairs is much more commonplace, occurring in certain types of natural radioactive decay here on Earth. And 'commonplace' is the right word: as we'll see later, even the humble banana is known to produce positrons. But antimatter produced in this way only survives for a fraction of a second. Almost as soon as it's created, it's going to encounter its normal matter counterpart and disappear in a tiny flash of gamma rays.

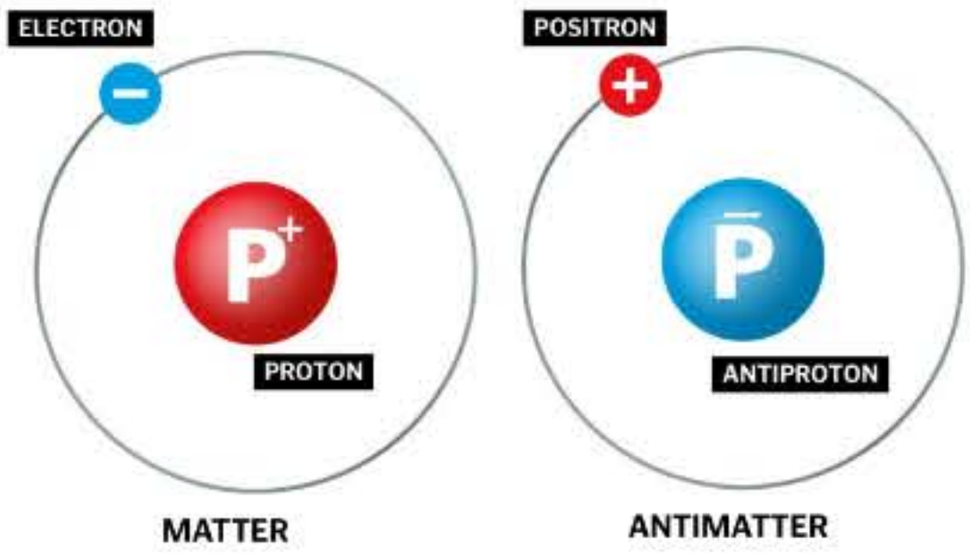


Source: https://commons.wikimedia.org/wiki/File:PET_Normal_brain.jpg

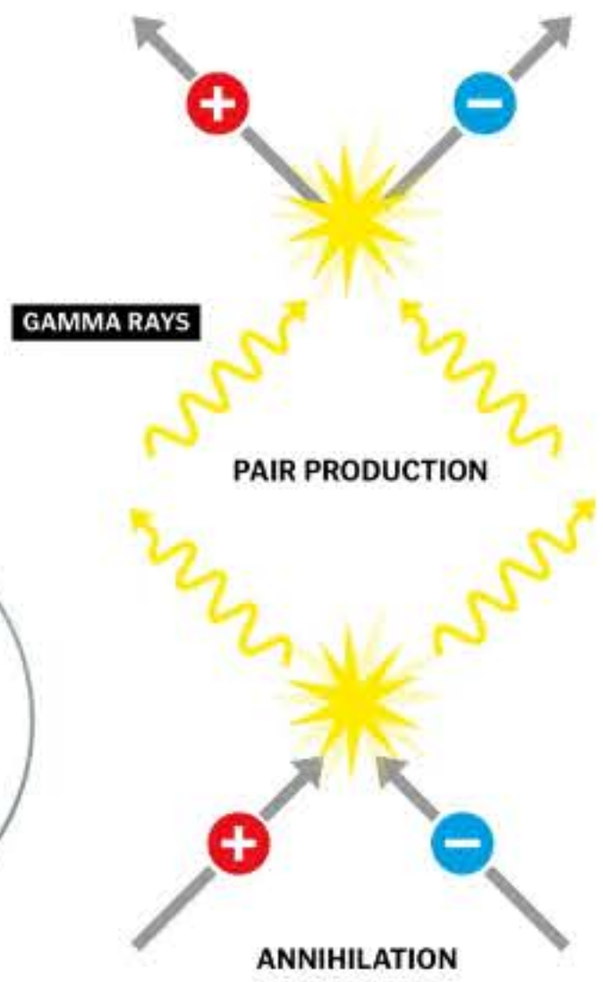
An interior view of a human brain, produced using a PET (positron emission tomography) scan

British physicist Paul Dirac predicted the existence of antimatter, based on theoretical equations, in 1928

Source: https://commons.wikimedia.org/wiki/File:Paul_Dirac_-_1933.jpg



Antihydrogen (right) looks like ordinary hydrogen (left), with an antiproton and positron replacing the proton and electron



An electron-positron pair can appear spontaneously with enough energy, or annihilate, producing the same energy

CERN's antimatter factory

It's common for particle-antiparticle pairs to be created in accelerators at CERN and similar laboratories. The huge speeds mean collision energies are easily high enough. But the resulting antiparticles are short-lived, before they're annihilated in further collisions with ordinary particles. The purpose of CERN's 'antimatter factory' – the only facility of its type in the world – is to create antimatter that lasts long enough to study it properly.

There are two tricks to this. The first is slowing the antiparticles to manageable speeds – the job not of an accelerator but a particle decelerator. Then the antimatter has to be confined somewhere so it can be studied, which is not an easy task, given that it would annihilate in contact with any kind of matter. The solution is to trap the antiparticles inside a strong magnetic field, where they can be used to make antihydrogen – an 'antiatom' consisting of a positron orbiting around an antiproton.

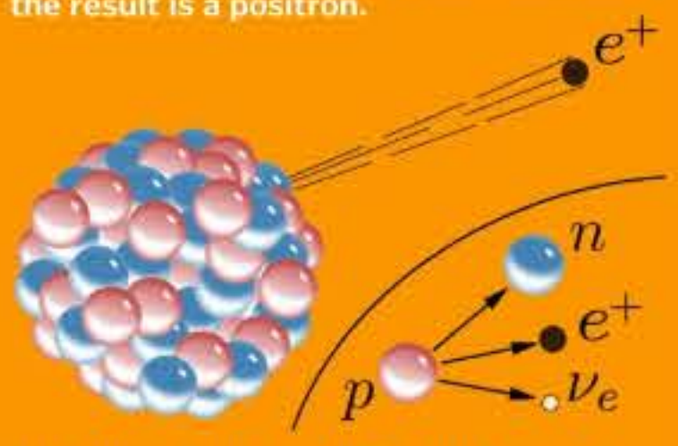
SOURCES OF ANTIMATTER

CERN may have the only antimatter factory, but there are other ways to make antiparticles

Everyday antimatter

Even atoms of ordinary matter sometimes produce antiparticles. The culprits are radioisotopes – atoms that are unstable because they have too few or too many neutrons. Several common substances contain a small proportion of isotopes like this, which decay to more stable forms by emitting high-energy particles. Usually these are ordinary matter – electrons in the case of beta decay, for example – but some radioisotopes also undergo 'beta-plus' decay, producing positrons instead.

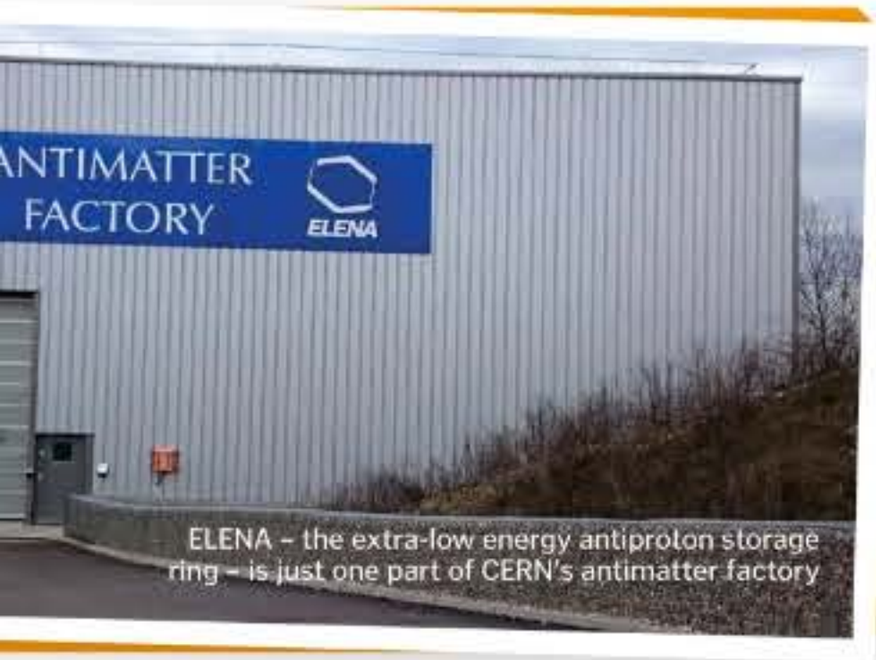
The positrons only last a fraction of a second before meeting electrons and annihilating to produce gamma rays. That's not as catastrophic as it sounds, because the energy of a single particle is tiny by everyday standards – which is fortunate, because there are positron-emitting isotopes inside your body. The commonest is potassium-40, which accounts for one in 10,000 of potassium atoms found in nature. It usually decays to regular beta-particles, but around 0.001 per cent of the time (1 in 100,000) the result is a positron.



A schematic illustration of 'beta-plus' decay, in which an unstable nucleus emits a positron (e^+)

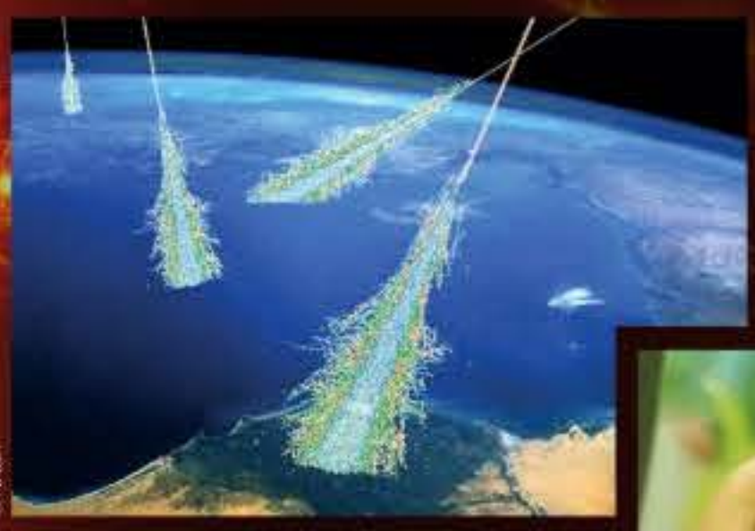
Source: https://commons.wikimedia.org/wiki/File:Beta-plus_Decay.svg

"Given enough energy, a particle-antiparticle pair can pop into existence from nowhere"



ELENA – the extra-low energy antiproton storage ring – is just one part of CERN's antimatter factory

© CERN



© NASA

Cosmic rays

A few of the fast-moving particles bombarding Earth are antiprotons produced by collisions in interstellar space. Many more collisions occur after the particles enter the atmosphere, creating further antiparticles.

© Getty

Bananas

That's right – bananas. They're rich in potassium, around 0.01% of it in the form of potassium-40, which occasionally emits positrons. An average banana produces around 20 positrons a day.

©NASA

Thunderstorms

In 2011, a NASA satellite observed antimatter particles being created above thunderstorms on Earth – a result of the high-energy gamma rays that can be produced by lightning flashes.

Source: https://commons.wikimedia.org/wiki/File:Ivy_Mike_-_mushroom_cloud.jpg

Nuclear explosions

Fortunately nuclear explosions are a rarity now, but during the heyday of H-bomb testing in the 1950s, the gamma rays they produced resulted in showers of electron-positron pairs.

Source: https://commons.wikimedia.org/wiki/File:PETCT.jpg

Positron-emission tomography

A PET scanner uses positrons from a radioisotope injected into the bloodstream to see inside the human body. It detects gamma rays produced when positrons and electrons annihilate each other.

AR ZONE!

AR ZONE! SCAN HERE

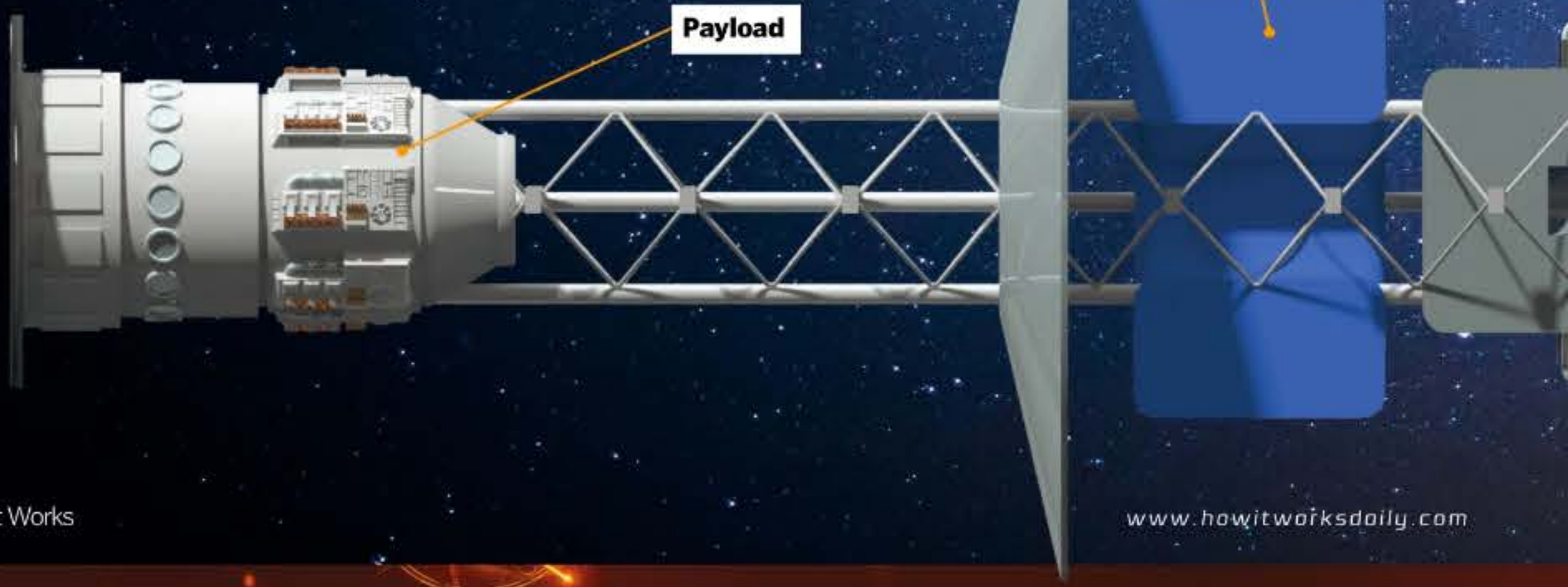
Payload
Depending on the application, the payload might be scientific instruments or even a crew module.

Payload fraction
Antimatter is far more efficient than conventional propulsion, so the payload can be a larger fraction of the total mass.

Deuterium tank
The basic propellant is deuterium – hydrogen with an added neutron – which is the ideal fuel for a nuclear fusion reactor.

A CONCEPTUAL ANTIMATTER ROCKET

Antimatter space drives aren't complete science fiction – here's a design proposal that might really work



The TV series *Star Trek* popularised the idea of antimatter-powered space drives

Positron source
This tank is filled with a radioisotope, such as krypton-79, which provides a continuous source of positrons.

Fusion reactor
As the positrons are produced, they're injected into a reaction chamber containing deuterium fuel, prompting it to undergo nuclear fusion.

Continuous operation
Unlike ordinary rockets, which are limited to short burns, the antimatter version is designed to operate continuously over long voyages.

Immediate use
Unlike other 'antimatter drive' concepts, the positrons are used as soon as they are created, so they don't require magnetic containment.

Immediate use

Positron source

Fusion reactor

Rocket nozzle
The high-energy charged particles produced in the fusion reaction are ejected through a standard rocket nozzle to produce thrust.

Continuous operation

5 FACTS ABOUT ANTIMATTER

1 A matter-dominated universe
Despite the perfect symmetry in their properties, there's a huge imbalance in the relative abundance of matter and antimatter. It's a cosmic mystery that scientists are still struggling to understand.

2 The most efficient explosive
Matter-antimatter annihilation is the only known process capable of converting mass into energy with 100 per cent efficiency. The most efficient nuclear weapons can barely manage 10 per cent.

3 A very scarce commodity
It's incredibly difficult to produce antimatter in any quantity. CERN and other laboratories around the world have created just a few billionths of a gram.

4 Does it fall up?
Antimatter might be so contrary it responds to gravity in the opposite direction to matter. Scientists don't think that's true, but they have yet to confirm it through experiments.

5 Your body produces antimatter
The human body contains potassium, a small fraction of which is positron-emitting potassium-40. You've probably produced a few antiparticles while you've been reading this magazine – with no ill effects!

Meet the LIVING FOSSILS

These creatures have survived asteroids, earthquakes and ice ages across millions of years to walk and swim the Earth today

Words by **Scott Dutfield**

The father of evolution, Charles Darwin, was the first to coin the term 'living fossil' in the pioneering book *On The Origin Of Species* in 1859. He used the term to describe living species bearing a physical resemblance to prehistoric species that once roamed Earth.

However, categorising animals as 'living fossils' has caused controversy in the scientific community because it implies that some of today's species have stopped evolving and remain unchanged from their ancient ancestors.

The truth about 'living fossil' species, such as crocodiles, is that they have very similar characteristics to a species that lived millions of years ago, rather than being unevolved for millions of years. To be classed as a living fossil a species must have had a significantly slower rate of physical evolution or show subtle morphological (physical) changes.

As evolutionary echoes, these modern-day doppelgängers give researchers a glimpse into their prehistoric timelines and offer suggestions as to why their morphology has gone almost unchanged for so long.

New additions to these evolutionary elites are still being discovered. In 2002, researchers unearthed the fossil remains of what was first believed to be a prehistoric chimpanzee in Barcelona. However, last year, after careful analysis, it was deduced that the fossils belonged to a giant flying squirrel (*Miopetaurista neogrivensis*), dating back 11.6 million years ago.

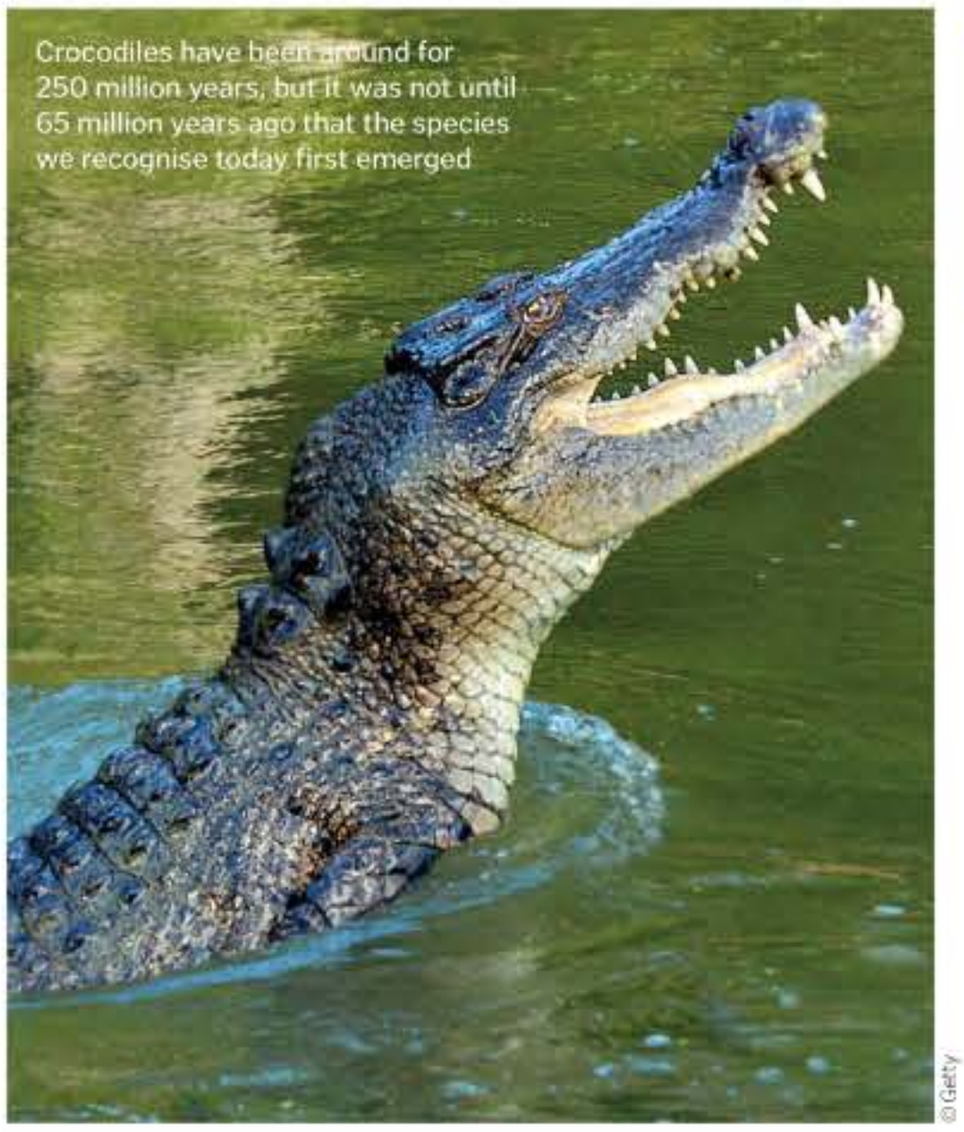
Nautilus

There aren't many species that can say they have lived to witness both the rise and fall of the dinosaurs, but nautiluses certainly can. Becoming giants of the sea around 500 million years ago, these ancient cephalopods owe their survival success to their natural armour. Nautiluses are the only cephalopods to have a fully enclosed shell, thanks to a fleshy trapdoor protecting the soft body that hides within.

At first glance, a nautilus may appear to be a floating snail, passively riding the underwater currents without any fins or limbs to guide its journey. However, it uses a water jet to propel itself through the sea. Through a siphuncle (a canal connecting living tissue to internal shell chambers), a nautilus can draw in and pump out surrounding water, allowing it to travel forwards and backwards. It uses the same method to ascend and descend: after expelling water from the shell, the nautilus becomes more buoyant and will rise; draw in more water and the cephalopod will sink.

Although this unique design has sustained these creatures for millions of years, they are now under threat of extinction from hunters fishing for their stunning shells.

These living fossils use their 90 unsuckered tentacles to catch prey such as crabs and fish



Crocodiles have been around for 250 million years, but it was not until 65 million years ago that the species we recognise today first emerged

Crocodile

As the poster species for living fossils, crocodiles have long been an example of how "if it's not broken don't fix it" applies when it comes to evolution. At the start of the Mesozoic Era some 250 million years ago, the ancestors of modern-day crocodiles began to walk the Earth. By the late Cretaceous Period, around 65 million years ago, prehistoric swamps and riverbeds were home to amphibious predators not dissimilar to the crocodiles we see today.

Sporting long and muscular snouts, scaled armour and short legs, the physiology of crocodiles is believed to have evolved from the need to explore new hunting territories because dinosaurs had monopolised the land. Finding relief from this competition in the water, crocodiles evolved to suit their new habitat. Eyes, ears and nostrils lie on top of a crocodile's head to keep them above the water line while the rest of the body is submerged, and the muscular fin-like tail offers both power and manoeuvrability in the water.

Although we can see evidence that modern-day crocodiles have maintained their shape for millions of years, the lineage of the species has diverged. Over time crocodilians have taken many different forms, even vegetarian species – a far cry from today's carnivores.

The last lizard

Now only found in New Zealand, tuatara (*Sphenodon punctatus*) once roamed around the world. These lizard-like reptiles were previously thought to be a member of the lizard family, but after careful consideration and a fossil trail leading back more than 200 million years, it was concluded that these reptiles are members of an exclusive group known as Rhynchocephalia, of which tuatara is the only living member. There was 24 genera of Rhynchocephalia, but competition with other, more adapted reptiles, such as crocodiles, resulted in all but one becoming extinct around 100 million years ago.

Tuatara is the last remaining member of the Rhynchocephalia reptiles

Prehistoric plants

Meet these thriving prehistoric plants

Cycad

Today cycads can be found on every continent except for Europe and Antarctica, and limited to tropical and subtropical areas. However, these plants once dominated the land as far back at 300 million years ago, with the earliest fossil records dating back to the Permian Period.

Monkey puzzle tree

Brushing shoulders with the dinosaurs during the Jurassic Period around 200 million years ago, monkey puzzle trees are among the oldest plant species to grow on Earth today. Living for 1,000 years or more, each tree and its limb-like branches are coated with tough spines for protection against hungry herbivores – both past and present.

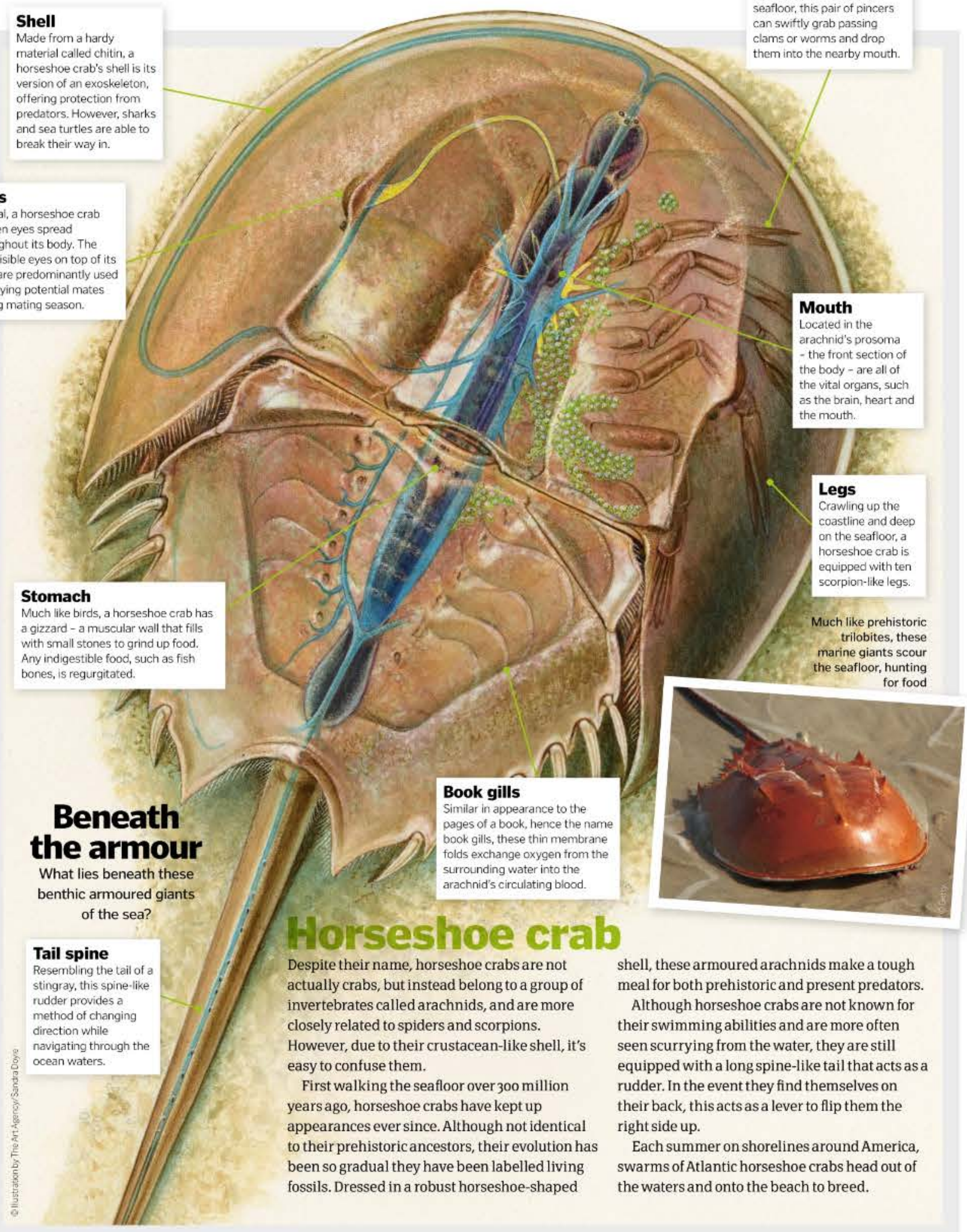
Maidenhair tree

The fan-shaped leaves of the maidenhair tree have been waving in the breeze since around 350 million years ago. It's believed that this tree species, also known as ginkgo biloba, was saved from the brink of extinction by early humans. Grown as a source of food, decoration and medicine, maidenhair trees have flourished alongside our own evolution.

Liverwort

Soft organic matter such as leaves are tricky to find as fossils due to their high rate of decomposition. But every so often one makes an appearance. In the case of liverwort, a hardy, rock-clinging plant, fossil evidence suggests that it grew at least 350 million years ago.

© Getty x4



Shell
Made from a hardy material called chitin, a horseshoe crab's shell is its version of an exoskeleton, offering protection from predators. However, sharks and sea turtles are able to break their way in.

Eyes
In total, a horseshoe crab has ten eyes spread throughout its body. The two visible eyes on top of its shell are predominantly used for spying potential mates during mating season.

Feeding pincers
Collecting food from the seafloor, this pair of pincers can swiftly grab passing clams or worms and drop them into the nearby mouth.

Mouth
Located in the arachnid's prosoma – the front section of the body – are all of the vital organs, such as the brain, heart and the mouth.

Legs
Crawling up the coastline and deep on the seafloor, a horseshoe crab is equipped with ten scorpion-like legs.

Stomach
Much like birds, a horseshoe crab has a gizzard – a muscular wall that fills with small stones to grind up food. Any indigestible food, such as fish bones, is regurgitated.

Book gills
Similar in appearance to the pages of a book, hence the name book gills, these thin membrane folds exchange oxygen from the surrounding water into the arachnid's circulating blood.

Tail spine
Resembling the tail of a stingray, this spine-like rudder provides a method of changing direction while navigating through the ocean waters.

Beneath the armour
What lies beneath these benthic armoured giants of the sea?

Much like prehistoric trilobites, these marine giants scour the seafloor, hunting for food

Horseshoe crab

Despite their name, horseshoe crabs are not actually crabs, but instead belong to a group of invertebrates called arachnids, and are more closely related to spiders and scorpions. However, due to their crustacean-like shell, it's easy to confuse them.

First walking the seafloor over 300 million years ago, horseshoe crabs have kept up appearances ever since. Although not identical to their prehistoric ancestors, their evolution has been so gradual they have been labelled living fossils. Dressed in a robust horseshoe-shaped shell, these armoured arachnids make a tough meal for both prehistoric and present predators.

Although horseshoe crabs are not known for their swimming abilities and are more often seen scurrying from the water, they are still equipped with a long spine-like tail that acts as a rudder. In the event they find themselves on their back, this acts as a lever to flip them the right side up.

Each summer on shorelines around America, swarms of Atlantic horseshoe crabs head out of the waters and onto the beach to breed.


Coelacanths are elusive living fossils, swimming deep in Indonesian and African waters

© Alamy

Coelacanth

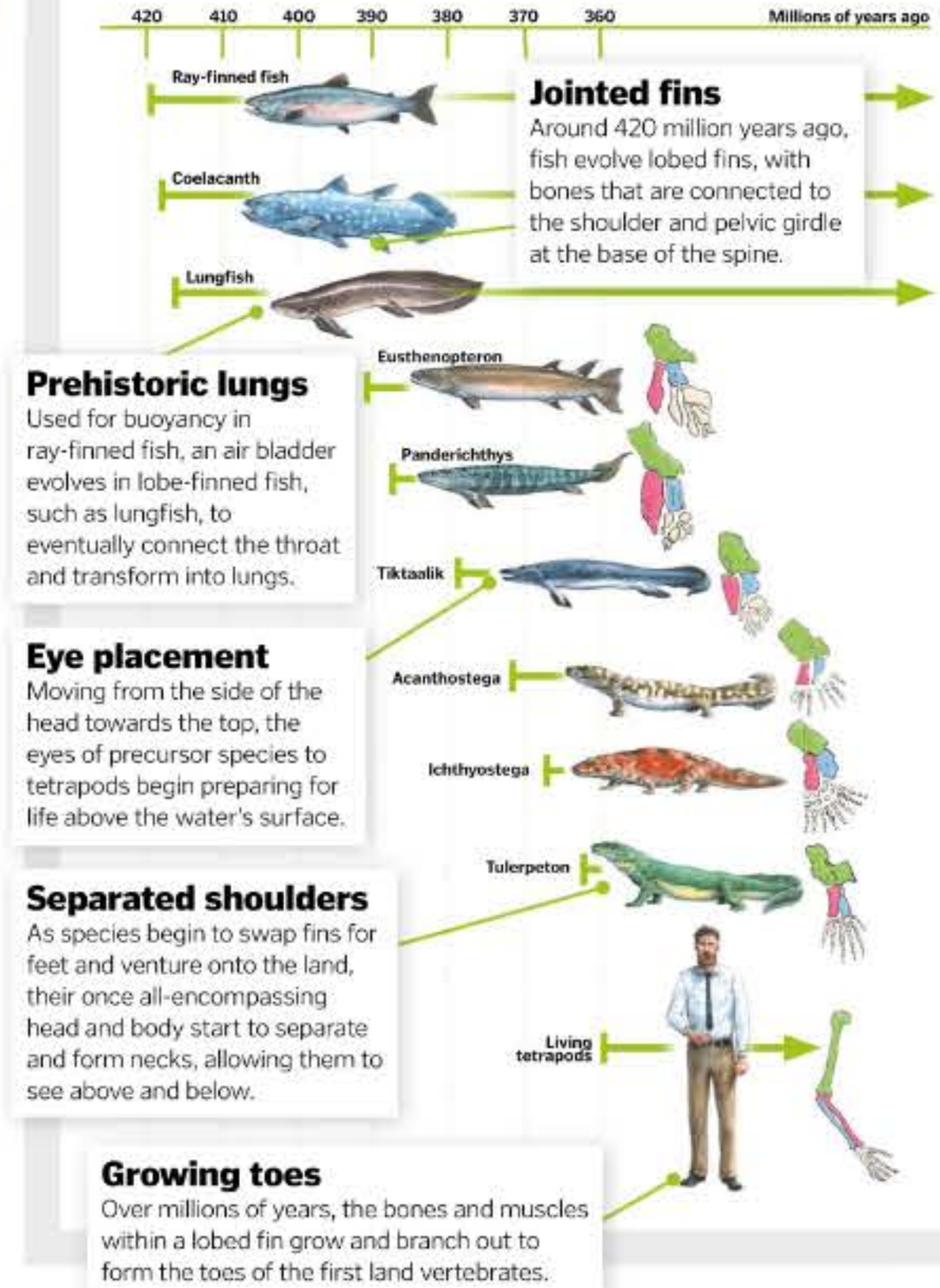
Taking a deep dive into the African waters surrounding the Comoros Islands, you might be lucky enough to spot a living fossil swimming near the seafloor. At up to two metres long, they're hard to miss. Once thought to be extinct, coelacanths have stood the test of time and remained relatively unchanged physically for over 360 million years.

There are currently two species of coelacanth – *Latimeria chalumnae* that dwell on the seafloor off the east coast of Africa, and *Latimeria menadoensis*, which swim deep in Indonesian waters. What makes these giant fish special is their fins. Typically, modern-day bony fish are ray-finned, meaning their flippers are made up of bony spines. Coelacanths are only one of two groups of fish to swim using lobed fins. Much in the same way our leg bones connect to our pelvis, lobe fins house an internal bone structure that has led scientists to believe their ancestry may be linked to the evolution of tetrapods (four-limbed vertebrates). However, having a lobed fin was as close as this fish got to sprouting legs.

To answer the question of which species started ditching fins for feet, the coelacanth's prehistoric cousin and fellow lobe-finned living fossil, the lungfish, may be responsible.

Ditching fins for feet

Although coelacanths still swim in the ocean, a group of their ancestors decided to escape the sea and walk on land. Here's how.



The original jellyfish

There's around 200 different species of comb jellyfish (Ctenophora) in the oceans, once thought to be the sister group to all other animals on Earth before sponges were proclaimed our evolutionary siblings. Comb jellyfish have been around for over 500 million years and were the first group of animals to swim using muscles. The name comes from the rows of structures called cilia, or combs. As cilia wave back and forth, a small current washes planktonic food into the jellyfish's mouths.


© Getty

Humans were once thought to be a long-distant relative of comb jellyfish

A case of misidentification

Although the term 'living fossil' has been awarded to species for more than 100 years, much like the principle of evolution, its accuracy has also changed over time. With the advancement in DNA analysis technology, scientists can determine how much change has occurred to a creature over time, or if it is what we think it is. Take the tadpole shrimp (*Triops cancriformis*), for example. Until 2013 these aquatic invertebrates were thought to be living fossils and had been linked to fossils dating back 250 million years. However, after researchers analysed the DNA of living tadpole shrimps, they discovered the species was not as old as they once believed and more likely evolved only 25 million years ago.

The uncertainty of this species' lineage stems from the similarity in appearance of different species of tadpole shrimp. Known as a cryptic species, one looks almost identical to the other, but they differ in their genetic makeup. In the 2013 study, 38 different species were identified based on genetics, with the majority yet to be taxonomically described.


Although it looks like a mini horseshoe crab, this tadpole shrimp doesn't share the same evolutionary lineage

© Getty

Christmas Island crabs

Follow the journey of millions of crabs as they make their way to the beach for an annual get-together

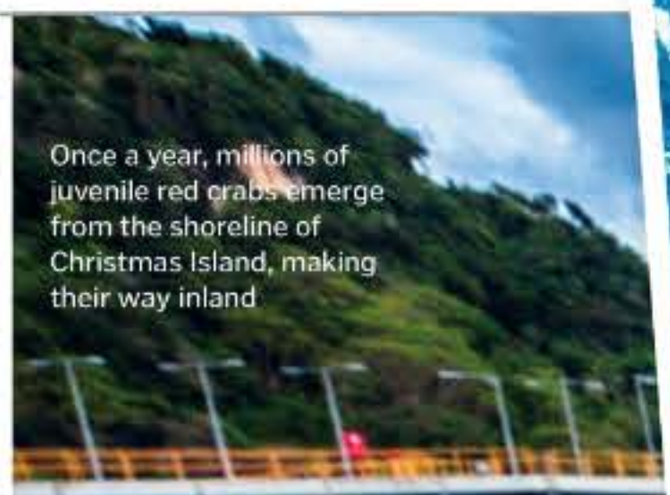
As the rainy season descends upon the beaches of Christmas Island in the Indian Ocean, resident red crabs realise that it's time to emerge from their forest burrows and begin a mass-migration to the beach. Flooding the island's roads and paths, a cascade of crimson crustaceans march in their millions to congregate on the shore to mate.

Typically occurring in October or November, the phases of the migration are tied to the phases of the moon. For a successful spawning, females must drop their eggs before the high tides on the last quarter of the moon (one week after a full moon). This is believed to be because of the small difference between the shoreline's low and high tide.

Leading the six-legged army are male red crabs, with the females not far behind. Arriving at the shoreline, males take a quick dip in the waters to rehydrate their tired shells, then move back to the land to dig their breeding burrows.

Once couples have met and mated, the female holds 100,000 eggs in a brood pouch on the underside of her body. Hauling her offspring out of the beach burrow and into the water, each female crab offloads its offspring over a period of five or six nights, before returning to the forests.

Over the next month, larvae will develop and hatch as shrimp-like megalopae, before growing into small, soft-shelled crabs in one or two days. Only five millimetres wide, many of these tiny crabs will not make the journey to the forest, thanks to the many ocean predators waiting in the waves. Those that survive the predators emerge in their millions on the island's beaches and make a nine-day journey into the forests.



Once a year, millions of juvenile red crabs emerge from the shoreline of Christmas Island, making their way inland

Christmas islands around the world

1 Christmas Island, Canada
Located in Nova Scotia, this 'Christmas Island' village is named after an indigenous Mi'kmaq family that lived there, who had surname 'Christmas'.

2 Christmas Island, Indian Ocean
Named on Christmas Day in 1643 by Captain William Mynors, this Indian Ocean island is part of Australia's external territories.

3 Christmas Atoll, Pacific Ocean
This Pacific paradise, also known as Kiritimati Atoll, is far from the typical frozen representation of Christmas. The tropical atoll was named on Christmas Eve in 1777 by Captain James Cook.

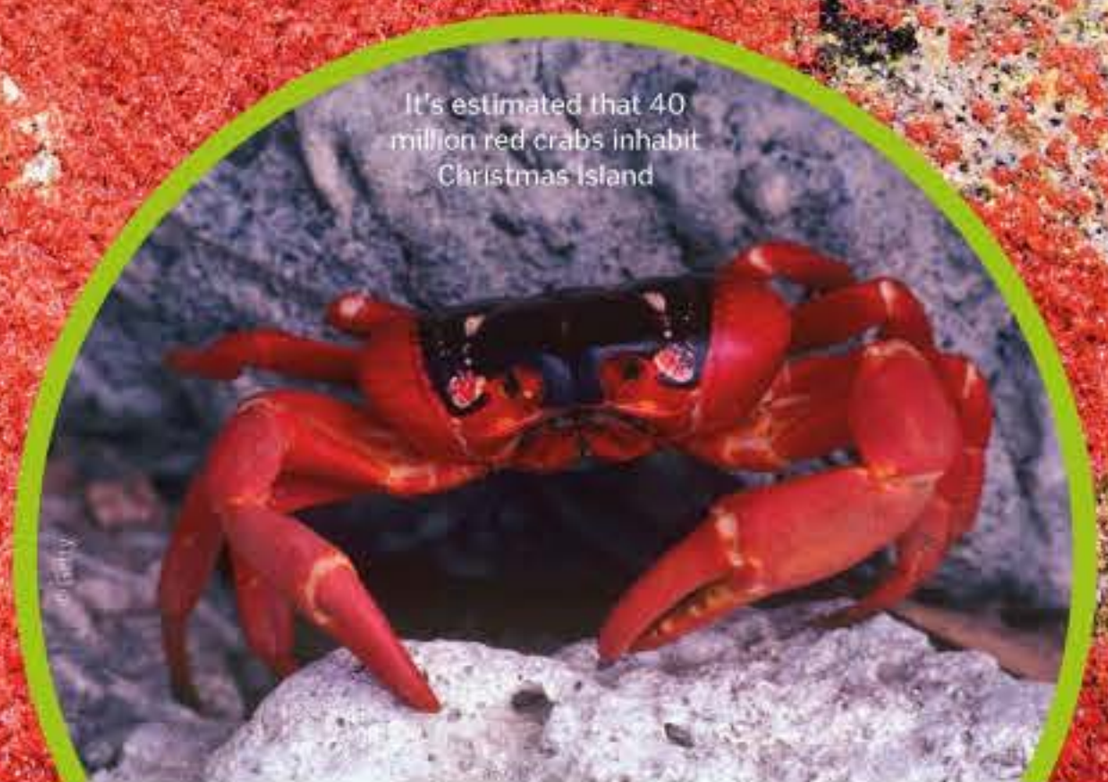
Shoals of newly hatched red crabs dominate the island's coastal waters, before making their way onto the land

The crab that stole Christmas

As well as being the home of the world's largest migration of red crabs, Christmas Island is also home to the world's largest land crab, the robber crab, also known as the coconut crab. Weighing around four kilograms, these colossal crustaceans spend their time climbing tree trunks in the pursuit of fruit and seeds. Not one to pass up a free meal, robber crabs will also feast on the flesh of deceased animals and hunt freshly hatched turtles.

The name robber crab comes from its attraction to the locals' belongings. Often found rummaging through residents' rubbish bins, robber crabs, just like magpies, enjoy the allure of shiny objects such as silverware.

Robber or coconut crabs can be seen clinging to trees or rolling coconuts across the ground



It's estimated that 40 million red crabs inhabit Christmas Island

What causes an avalanche?

With 1 million avalanches occurring each year, what creates these snowy landslides, and how can we predict them?

Words by **Ailsa Harvey**

Mountaintops are like a continuous dumping ground for the clouds, with some accumulating metres of snow every day during winter seasons. Snowy peaks usually remain calm in blissful winter wonderland scenes, but the sudden arrival of icy clouds can dramatically transform them.

Looking at a snow-covered mountain, it is difficult to determine the composition of the icy layers below and the strength at which snow clings to the mountainside. Just one wrong foot placement, a day of heavy snowfall or even a loud sound can send a huge portion of a mountain's white coating racing down towards the bottom.

This freefall of snow, ice and sometimes rocks down a mountainside is called an avalanche, and it is the cause of over 150 deaths around the world each year. Avalanches can reach speeds of 130 kilometres per hour in the space of just five seconds, giving little warning to anyone in its path. A combination of three factors determine how susceptible a mountainside is to an avalanche. This is known as the 'avalanche triangle', consisting of terrain, weather and snowpack. An incline of between 30 and 45 degrees will accumulate enough snow for avalanche conditions. Weather is important to factor in too, as wind, temperature and snowfall all contribute to the risk of an avalanche. The final side of the triangle highlights the need for understanding the snowpack and the behaviour of the different layers of snow. Digging into the snow and observing layers can reveal a lot about the history of the snowfall, and can be key in determining avalanche-prone areas.

Not all avalanches hurtle down the slopes at equal speeds, as avalanche properties can vary.

The world's biggest avalanche

Mount Huascarán is the highest point in Peru, standing 6,768 metres tall. It's a relatively peaceful peak, but on 31 May 1970 it was the scene of the biggest avalanche on record.

When its north slope collapsed, around 2.3 million cubic metres of debris was sent hurtling down the mountain face at 160kph. At the bottom, nothing and no one stood a chance as they were covered by the massive frozen sheet. The ice, mud and rock travelled almost 18 kilometres in total, burying two towns in 90 metres of debris, and killing more than 20,000 people.

The huge volume of snow involved in this avalanche was shifted by the shocks of an nearby earthquake being sent through the ground below, shaking the snow off the mountain. All avalanches accumulate debris as they move, and the large volume of snow that was initially displaced snowballed to create a massive avalanche. The earthquake originally moved a mass about 1.6 kilometres long and 910 metres wide.

The imposing face of Huascarán, seen from the town of Yungay, buried by the 1970 avalanche

Damp snow can move fluidly, almost like icy cement, while other avalanches proceed in a rough tumble, projecting clumps ahead of them in a disorganised descent. One thing all avalanches have in common is the ability to engulf everything in their path. If not for the impact on human life, avalanches would be a breathtaking display of gravity's destruction.

Mountain-dwellers such as skiers and mountain climbers are inevitably at the highest risk, and their movements are often the cause of an avalanche. Recently, headlines have shown how even those who know the mountains better than anyone can be caught up in an avalanche tragedy. In April 2019, three professional climbers lost their lives as they were swept down the mountain in Canada's Banff National Park. The two Austrian climbers, David Lama and Hansjörg Auer, and one American, Jess Roskelley, were some of the world's most accomplished climbers.

In 90 per cent of avalanche incidents involving people, one of the victims is thought to have triggered the avalanche by being on the slope at the wrong time. But as snow can travel for kilometres around, villages and towns situated in the shadow of a mountain can also fall victim to the snow. Whole towns have been known to disappear beneath these deadly deposits.

The key to predicting incoming avalanches comes from analysing the layers below the surface snow, and understanding the snow's placement on the mountainside. A high liquid-water content within the snow increases the chances of snow slippage, while more snow on a mountain's slope increases the pressure at the deepest point, raising the risk of the snow breaking off and sliding. In theory there are crucial signs to look out for, but in practice nature includes so many variations and additional factors to consider that avalanches are as difficult to predict as the weather.

To track conditions around avalanche-prone areas, scientists closely follow weather predictions alongside data from previous avalanches. Studying the physics of avalanches, researchers found that a slight drop in temperature can turn a slow avalanche into a deadly 'dry' one. Depending on how high-risk an avalanche is thought to be through mountain analysis, explosives are sometimes used in areas such as ski resorts to force avalanches to take place prematurely, when the lower volume of snow will create less danger. Additionally, dams are built to reduce the destruction of these premeditated avalanches.

Although scientists can attempt to predict the likelihood of an avalanche, it is impossible to keep track of conditions everywhere in the world. With 12 per cent of the Earth's surface permanently covered in snow and ice, and with this percentage increasing during winter seasons, the surprise factor and instant danger created by a snow slip makes these almighty and terrifying spectacles as dangerous a phenomena as ever.

Rescue teams carry probes to measure the depth of burial following an avalanche

© Getty

5 FACTS ABOUT TYPES OF AVALANCHE

1 Dry slab
Snow breaks away in cohesive slab pieces. These slide over the snow that's underneath and need to be stronger than the snow below it. Typically slabs are half the size of a football field and between 30-60 centimetres deep.

2 Powder (dry)
Fresh snow can rush down a mountainside in large, fluffy clouds. Beneath the powder is the avalanche's core; a mix of 70% air and 30% ice particles. The surrounding powder is made of 99% air. When the avalanche stops, the particles push together, forming densely-packed snow.

3 Wet
Warmer temperatures and rain can cause water to enter the snow, creating a weaker snowpack. Wet avalanches can occur in slabs or sluffs, but they travel at a slower speed than a dry avalanche. Fewer deaths are caused each year by wet avalanches.

4 Glacier
When large sections of ice break from the main glacier, an icy avalanche can form. Glacial ice creates extremely dense and high-speed avalanches. Falling ice blocks can also cause slab avalanches by displacing the snow below.

5 Sluffs
Small, loose-snow avalanches are called 'sluffs'. These tend to begin below a weight or object pushing on the snow – such as the weight of a skier – so people are often saved from being carried away. Usually, they form at one point and fan out below.

© Illustration by Ed Crooks

Avalanche rescue dogs

How and where do you find survivors in the aftermath of an avalanche? The mountain's contents sit at the foot, with any number of people lying below it, having been swept for kilometres around. 90 per cent of people will survive an avalanche if they are recovered within 15 minutes of being buried. 30 per cent will survive after half an hour and only 10 per cent will make it if they're left for over two hours. It is therefore vital that rescue teams work as quickly as possible.

This is where dogs come in. Dogs are crucial members of avalanche rescue teams, as their enhanced sense of smell enables them to detect bodies far more quickly than humans can. One avalanche dog can search 10,000 square metres in 30 minutes. It would take 20 people about four hours to cover the same area.

Under the debris, panicking victims give off a particularly strong scent, which rises through the snow. When a dog senses it, it will follow its nose to the area. Then, burying its head in the snow, a rescue dog will pinpoint the area where the odour is strongest. The dog will start digging when it thinks it has the right spot, identifying the person's position.

©iStock

Where a rescue dog begins digging, the team can start to assist with shovels, enabling a more targeted, localised search

Source: Wiki / Uwebart

The light area of this image shows where snow and rock swept across the town of Yungay after part of Mount Huascarán broke away

How does an avalanche happen?

The changing properties of snow layers react with each other before crashing down

Track zone
The track is the length of the path taken by the descending snow. Within this area the avalanche's highest speed will be attained.

Run-out zone
This is where the snow comes to a halt after a rapid deceleration. The avalanche stops and becomes a pile of frozen debris.

Snow powder
If the avalanche is moving quickly enough, some of the snow can mix with the air to form an engulfing cloud of powder snow.

10 of the world's deadliest avalanches

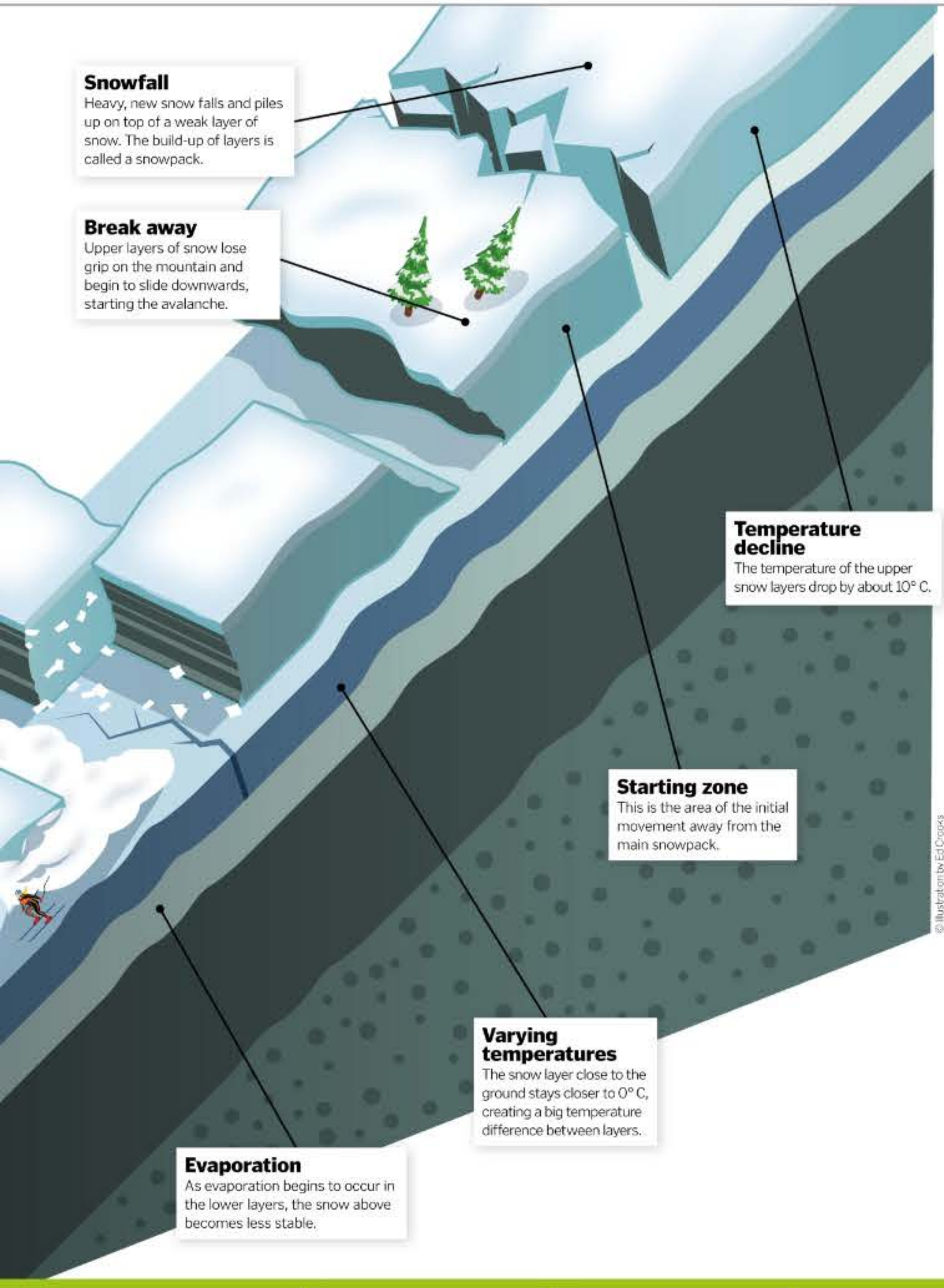
TYROLEAN ALPS
13 December 1916
Death toll: 10,000
During World War I, a combination of heavy snowfall and explosives caused a series of avalanches over a 24-hour period. The victims were mainly opposing Italian and Austrian soldiers. 300 Austrians perished in a single avalanche near the summit of Mount Marmolada.

RANRAHIRCA, PERU
10 January 1962
Death toll: 3,500
The aftermath of a snowstorm the day before saw heaps of melting snow tumble down Mount Huascarán, before dropping over 9,000 metres into the canyon below. The avalanche destroyed nine towns and several more villages as it swept downwards for 15 kilometres.

PANJSHIR, AFGHANISTAN
24-28 February 2015
Death toll: 316
A series of avalanches obliterated 1,200 homes in villages around Panjshir. With limited resources in the country, rescue teams were unable to reach the victims as quickly and efficiently as they needed to, and there was a call for global assistance.

SWISS-AUSTRIAN ALPS
1950-1951
Death toll: 265
During the 'Winter of Terror', the Alps was hit with its worst avalanche season. While the total number of avalanches across the whole year was unrecorded, hundreds of deaths occurred in a three-month period in which 649 avalanches took place across the region.

LAHAUL VALLEY, INDIA
March 1979
Death toll: 200
During five days of snowstorms in the mountains, a series of avalanches struck the Lahaul-Spiti region of the Himalayas, increasing the number of casualties and resulting in snow six metres deep covering the valley below the peaks.



Snowfall
Heavy, new snow falls and piles up on top of a weak layer of snow. The build-up of layers is called a snowpack.

Break away
Upper layers of snow lose grip on the mountain and begin to slide downwards, starting the avalanche.

Temperature decline
The temperature of the upper snow layers drop by about 10° C.

Starting zone
This is the area of the initial movement away from the main snowpack.

Varying temperatures
The snow layer close to the ground stays closer to 0° C, creating a big temperature difference between layers.

Evaporation
As evaporation begins to occur in the lower layers, the snow above becomes less stable.

HOW TO SPOT AN AVALANCHE

Search for instability
Looking for evidence of recent avalanches is a good starting point. Observe the whole landscape for any debris that could have been moved by a snow slide. Signs of activity means the rest of the snow could be unstable.

Check for cracking
If the snow is cracking, it's a sign of unstable slabs in the area. An unusual number of cracks underfoot or cracks that suddenly appear are a good indication of moving snow, and possible avalanches.

Spot significant snowfall
If a large volume of snow has fallen in the last 24 hours, it won't have had time to compact together in a stable layer. Introducing rain or wind to a large amount of fresh snow is a recipe for an avalanche.

Listen for thuds
Sounds from below the ground can be caused by snow collapsing in deeper layers. This is a warning sign that there are weak snow layers below that could trigger a slide. Often the ground can feel hollow underfoot.

Monitor temperatures
If the air has been getting warmer, rising above 0° C, it can cause partial melting within the snow layers. Melting makes snow heavier, and as it becomes wetter it gets slipperier. This can cause wet avalanches.

Understand the terrain
Terrain can reveal a lot about the potential for an avalanche. Avalanches are most likely to occur on slopes between 30 and 45 degrees. In winter, slopes on the south side of a mountain are more stable than the north-facing ones.

SALANG PASS, AFGHANISTAN
8 February 2010
Death toll: 165
Several days of heavy snow caused over 20 avalanches in a mountain pass that connected Kabul and northern Afghanistan. The avalanche covered 3.5 kilometres of road in snow and ice and 2,500 people had to be rescued from their cars.

NORTH OSSETIA, RUSSIA
20 September 2002
Death toll: 150
After part of a glacier collapsed on Mount Kazbek, 20 million tons of debris began to cascade down the mountainside, destroying several villages. One of the casualties was Russian actor Sergei Bodrov Jr, who was struck along with his crew while shooting a film there.

SIACHEN GLACIER, PAKISTAN
7 April 2012
Death toll: 140
129 soldiers and 11 civilians were killed when an avalanche covered a Pakistani military base and trapped them in deep snow. The incident occurred at an altitude of around 4,000 metres. Rescue efforts were hampered by the freezing conditions.

WASHINGTON, USA
1 March 1910
Death toll: 96
Following a nine-day blizzard, with some days seeing 30 centimetres of snowfall an hour, a lightning strike caused a large mass to break from Windy Mountain. The build-up of snow crashed into a train depot. The nearby town of Wellington was later renamed Tye due to negative associations.

BLONS, AUSTRIA
12 January 1954
Death toll: 57
Often considered Austria's worst avalanche, it consisted of two slides nine hours apart. The first was a dry-snow avalanche that demolished the town of Blons. Following this came another, travelling 1,200 metres in less than 60 seconds, burying the village and the team of rescuers.

O Christmas tree worm

You'll find no festive spirit in these defensive, unsociable creatures

Found far from the cold of the North Pole, *Spirobranchus giganteus* is a species of tropical polychaete (bristle) worm that lives in warm waters from the Indo-Pacific to the Caribbean and makes its home on living coral. Young worms burrow into the coral before secreting a hard tube, where they remain for the rest of their lives. As they can't flee from danger, the worms must rely on quick reactions and a plug-shaped structure called an operculum to keep them from becoming meals for passing fish.

Spirobranchus giganteus gets its nickname, the Christmas tree worm, from the pair of unusual cone-shaped crowns protruding from its head. These are the radiolar crowns – sets of delicate tentacles that supply the worm with everything it needs to stay alive. When a Christmas tree worm feels safe, it pushes the crowns out of the tube so they can waft in the open water, where they perform two vital tasks: collecting food and acting like gills to aid respiration. Microscopic hairs cover each radiole, trapping plankton and other particles of food that drift past and transporting them down to the worm's mouth.

Being sessile creatures that remain in one spot forever, there's no chance of a holiday romance for Christmas tree worms. Reproduction is a much more practical affair for this species; from their tubes, worms send sex cells out into the water to meet and combine with gametes (mature cells) from other individuals. Larvae resulting from the mass spawning floats through the ocean until they reach coral suitable for burrowing.

© Getty

Christmas tree worms display huge variation in radiolar crown pattern and colouration

On the lookout

Although Christmas tree worms might not appear to be doing anything as they sit in their tubes and filter food, they're constantly watching for signs of danger. The eyes on their head aren't much use as they can't see out of the tube and into the surrounding water, but the radiolar crowns more than compensate with their 360-degree surveillance system.

The hundreds of eyespots dotted all along the radioles have evolved to respond to silhouettes in the water above. When another animal looms into view, signals from these light receptors trigger the Christmas tree worm's efficient nervous system, prompting a rapid withdrawal of the crowns, so the worm is sealed inside its tube before a predator can try to take a bite.

© Getty

Christmas tree worms dart back into their tubes in a fraction of a second when shapes pass overhead

© Getty

The defensive operculum distinguishes members of the family Serpulidae from other closely-related worms

© Illustration by The Art Agency/Nick Sellers

AIRFIX BOARD GAME

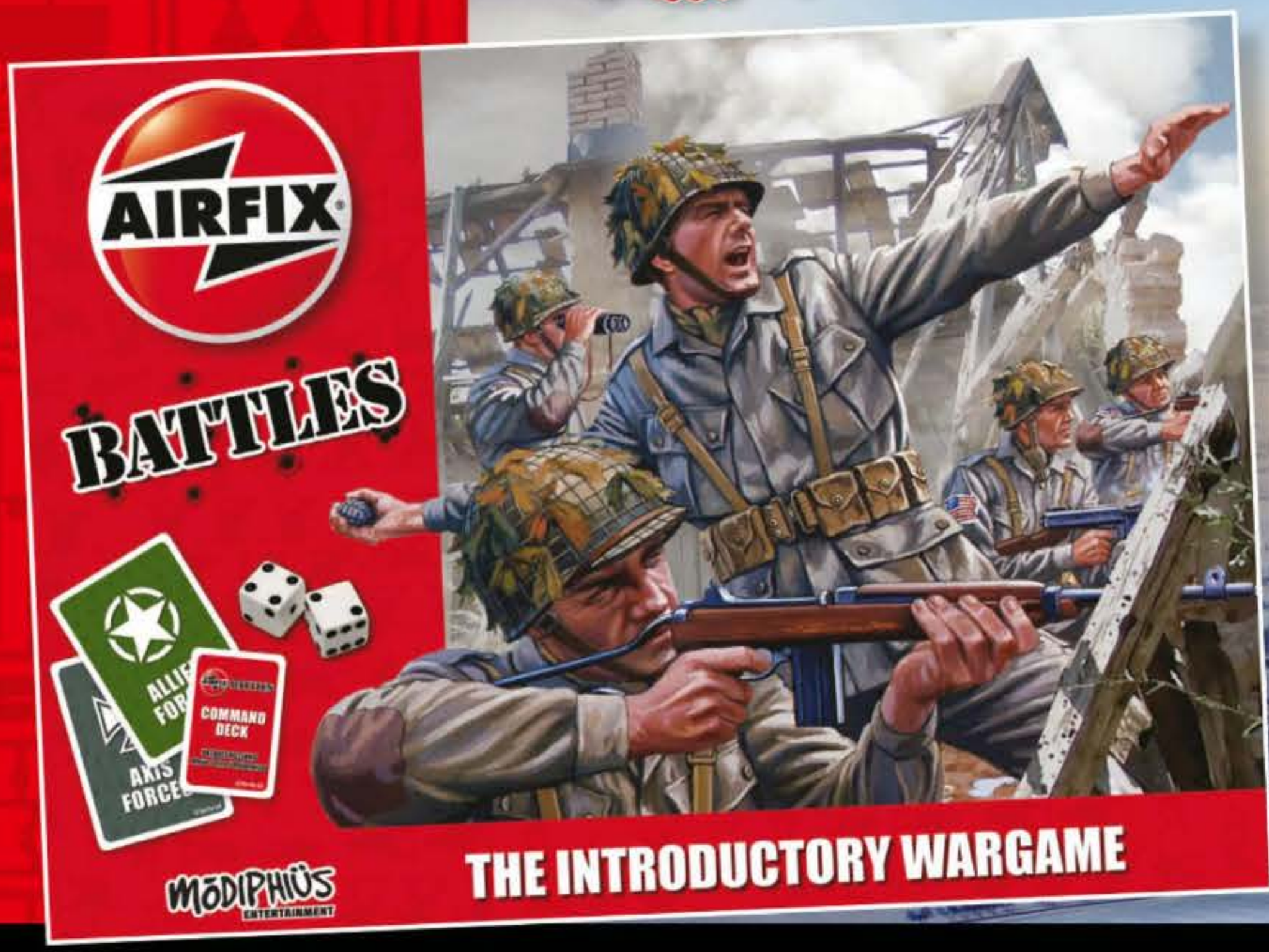
A fast and fun introductory wargame playable with all your Airfix figures and vehicles. Airfix Battles comes with everything you need to play exciting World War II battles straight out of the box, including die-cut carboard counters for tanks, infantry and guns in case you don't have any figures to hand.

BATTLES – The Introductory Wargame

Airfix Battles lets you plan your army using the Force Deck. Draw the cards or select the ones you need to build an exciting army to challenge your friends. Set up the battle using step-by-step instructions in the Mission Book and you're ready to play. Each player has a hand of Command Cards to move and fight their forces, bring in airstrikes or artillery support. You never know what your opponent is going to do next!

Contents:

- 2 x Double-sided A2 (420mm x 594mm) maps
- Over 100 carboard counters of tanks, infantry and terrain
- 1 x 16 Page Mission Book
- 1 x 24 Page Rule Book
- 1 x 54 Card Force Deck
- 1 x 54 Card Command Deck
- 10 x Six-side dice



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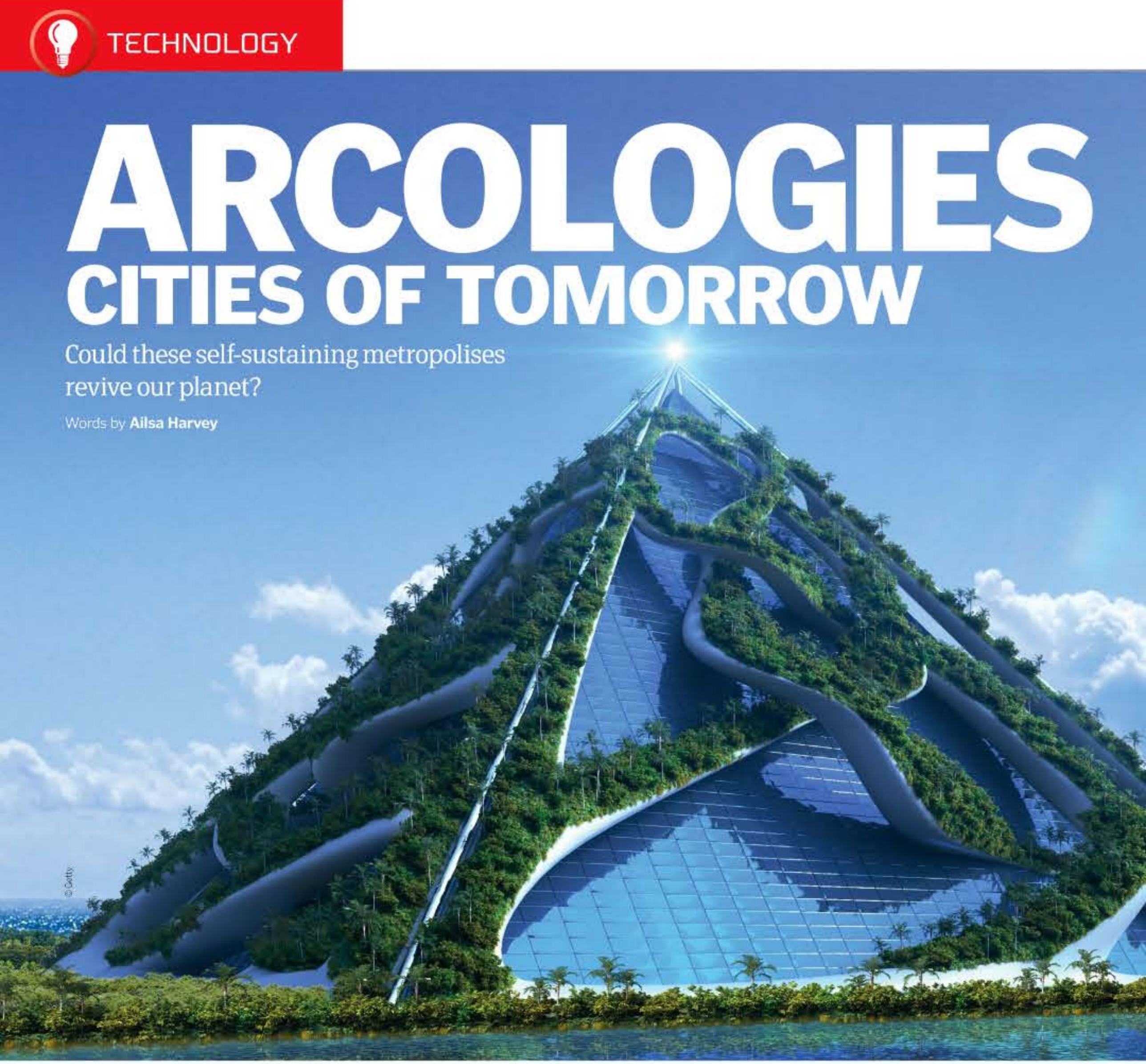
ARCOLOGIES
CITIES OF TOMORROW

Could these self-sustaining metropolises revive our planet?

Words by **Ailsa Harvey**



© Getty

As a species, we sometimes live in our own little bubble. Using the resources available to us for a variety of needs, we have caused a significant impact on the planet. Now plans are in place to use our own bubble for the better: to literally live in one.

To sustain our population while helping to prevent damage to the world, we could soon settle into newly designed cities called arcologies. Many different habitat variations are being worked on, with most of them including natural, alternative ways to sustainably source enough energy for those who live there.

Arcology is a futuristic initiative that aims to condense settlements into self-sustained cities that limit human impact on the environment. The name and idea came from Paolo Soleri in 1969, who decided to merge concepts of architecture with ecology. His proposal focused on providing for the essential needs of our population in an environmentally friendly design. Current architecture means today's cities and towns are dominated by low-rise buildings and car-dependant travel. In Soleri's alternative, giant structures would be built for the most efficient use of space. The majority of arcology designs showcase high-rise constructs that accommodate thousands of people.

But how will these gigantic habitats reduce our impact on the planet? Being densely populated, large amounts of energy would need to be cultivated within a relatively small area. Soleri's first design included concrete domes, placed to maximise their ability to capture the heat and light energy from the Sun at all times, even when the Sun's at its lowest in the sky and during the winter. This had the added benefit of creating shade during summer.

One of the drawbacks of having a number of different arcologies is the issue of separation. Before the world commits to these living arrangements, all our basic human needs have to be catered for within these settlements, including the requirement that we can remain connected to the outside world in some way.

Feeding the thousands

Where are all these arcology residents going to source their food from? One proposed design is a vertical farm. Farmland currently takes up around 11 per cent of the Earth's land, but if we stacked these fields, we could use the same area but on multiple levels, so more space can be left for nature.

This design displays an impressive 15-storey farm with a total area of 5,200 square metres of space in which to grow crops. The building is separated into wings to maximise sunlight. This could provide 1,000 people with their basic calorific needs, and in embracing a plant-based diet, production of harmful emissions would be reduced.

As part of the process, the arcology inhabitants would assist production. During waste treatment, methane would be extracted and used to run generators. The system has other solutions that ensure no material is wasted. Any water not used in farming would be collected at the bottom, condensed by dehumidifiers and returned to living blocks to be used in other ways.

Most water consumed by plants is returned as water vapour, and dehumidifiers can collect water for residents

Nobody wants to feel like they are in a cage, so to tackle this issue, shuttle designs are being explored for travel between settlements, and some of the planet's natural environment could be incorporated within the structures.

Though the positive impact of arcologies can be predicted, any detrimental effects on the environment that isolating us from the rest of the planet might have is less clear. Where a physical barrier will seclude our species, there is no way of knowing how this will influence ecological relationships with outside organisms. Arcologies, therefore, are certainly much more than just an architectural challenge, but represent a significant change for the whole planet.

www.howitworksdaily.com

Today's arcology designs

Self-sustaining settlements are already being planned across the world

Over 40,000 people visit Arcosanti every year

© Carvell

Arcosanti

Location: Arizona, USA

Designed by Paolo Soleri himself, this arcology for 5,000 inhabitants has been a work in progress since 1970. Situated at an altitude of over 1,000 metres in an isolated desert, the site is currently used as a prototype to demonstrate the possibilities of arcologies to thousands of visitors each year.

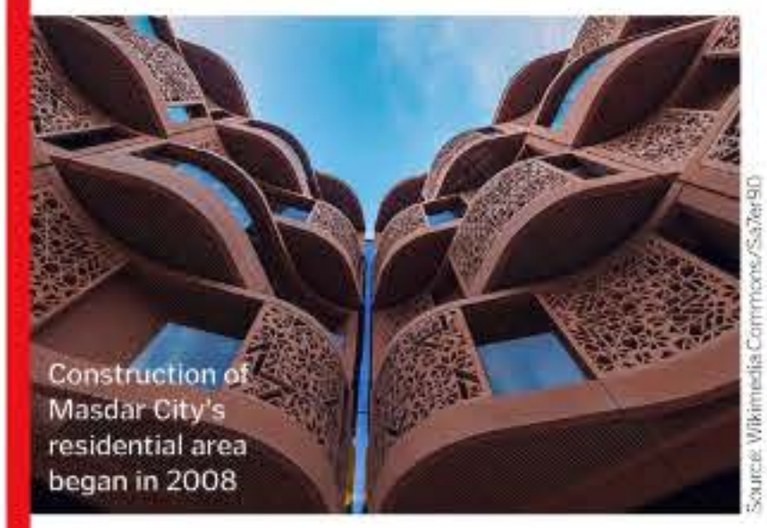
Crystal Island will contain a school for 500 pupils

© Foster & Partners

Crystal Island

Location: Moscow, Russia

Currently postponed, this arcology was to have the largest floor space on the planet (2.5 million square metres). Its buildings will be encased in one huge breathable tent. Being sealed in winter will help to conserve heat, while being open in the summer months will help to naturally cool the interior.



Construction of Masdar City's residential area began in 2008

Source: Wikimedia Commons/Sa7er90

Masdar City

Location: Abu Dhabi, UAE

This settlement's primary aim is to reduce fuel consumption and pollution. Powered entirely by renewable sources such as solar panels, wind farms and geothermal energy, it will also have a solar-powered desalination plant, which will provide clean, fresh water, and most of the water will be recycled and reused.

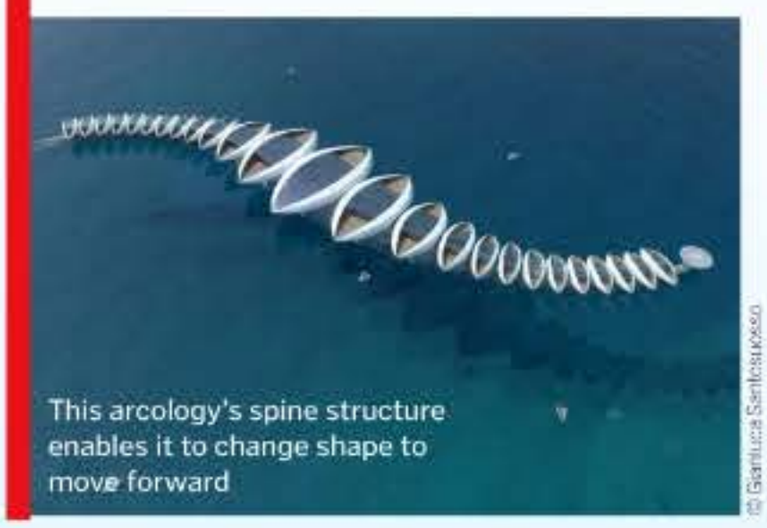
The building's eight modules can extend their hydraulic legs to overcome snow accumulation

© Hugh Broughton Architects

Halley VI Research Station

Location: Antarctica

In remote areas of climate-sensitive Antarctica, research teams are already utilising self-sustaining habitats in the challenging environment. Operated by the British Antarctic Survey, this research station is used for Earth, atmospheric and space weather observation.



This arcology's spine structure enables it to change shape to move forward

© Gianluca Santilli/Vizzo

HYPERcay

Location: The oceans

This building concept was inspired by cruise ships, but there's more to it than leisure. Self-contained, with solar panels, vegetable gardens and rainwater-collection facilities, this arcology floats on water, enabling mankind to adapt to Earth's rising sea levels. It will use its unique shape to generate propulsion.

AR ZONE!

LEAN LINEAR CITY

Combining city life with nature, this proposed arcology is an eco-friendly living arrangement that doesn't isolate its communities from other settlements

AR ZONE! SCAN HERE

Green areas
Acknowledging the need for the occasional escape from city life, people will be able to find natural spaces dispersed through the arcology to dilute urban density.

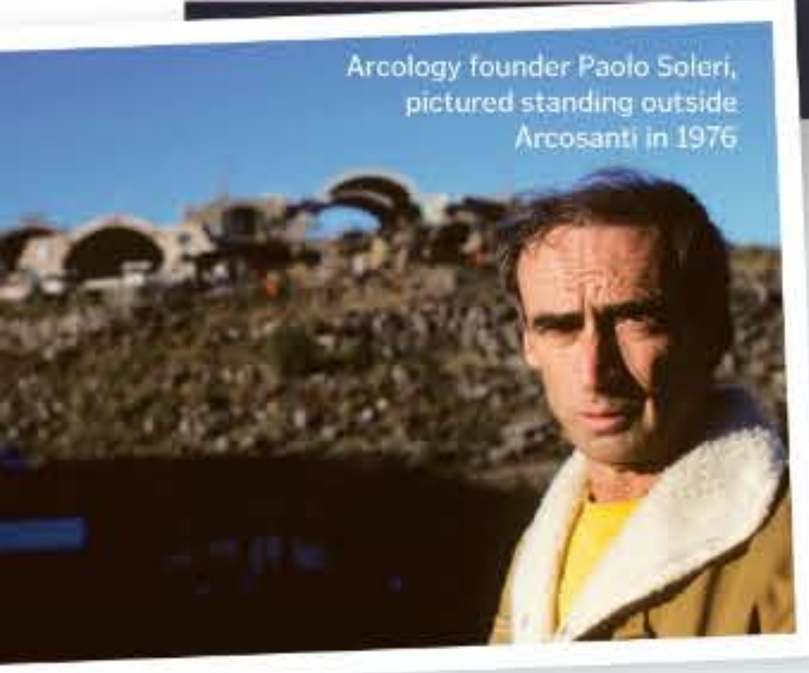
Light well
Making the most of an area as living space means that some residents stay in rooms deep in the centre. Light wells allow daylight to enter, brightening up areas that would otherwise have no natural light.

Main structure
At over 20 storeys high and stretching for many kilometres, two main structures will be built in modules. These modules could accommodate 3,000 residents each.

Wind energy
Windmills are placed on top of buildings, in a prime position to utilise the wind for energy.

Connecting people
There are urban nodes throughout the linear architecture. Larger open spaces are round and enable communities to meet.

Greenhouses and energy apron
Greenhouses attached to the outside of the buildings can be used for agriculture and to trap heat from the Sun.



Arcology founder Paolo Soleri, pictured standing outside Arcosanti in 1976

© Getty

Multifunctional bridge
While bridges add to the sense of connection, they can also act as a dam for the arcology's water supply.

This is New Orleans Arcology Habitat (NOAH); a floating design with a shape that enables wind to blow through it

© E. Kevin Schroeder

Architect Richard Buckminster Fuller designed this arcology in 1971, describing it as a "practical way for humans to live together economically"

© Steve Yevington

Solar powered
Any sunlight hitting the arcology will be used to produce renewable energy through solar panels.

Public transport
Walking is the main mode of transport around this city. However, there are local shuttles and moving walkways to take people to other arcologies or modules.

Streams
Water features are supplied in recreational areas. This water is also supplied for agricultural purposes and flows to water treatment plants.

© Illustration by Nicholas Forder

© Tony Webster

Minneapolis skyways show how some cities already use connected architecture

Inside the Nintendo Switch Lite

We crack open and tinker with the console gaming sensation's new little brother

Nintendo's Switch hybrid console has taken the gaming world by storm since it launched in 2017. The console's unique ability to plug into the TV for Full HD gaming at home, then switch (get it?) to a portable console by simply lifting it out of its dock has made it a firm favourite with gamers who want to play great-looking games like *Super Mario Odyssey* on the go.

But everyone plays the Switch differently, and it seems a lot of players prefer to play exclusively on the console's built-in screen. So Nintendo has created a new version of the console that can only be played undocked – the Switch Lite.

It's smaller, lighter and doesn't support the Joy-Con motion controllers that were included with the original Switch. Instead, the controllers are built in as part of the console itself. The screen is a little smaller, too – 5.5 inches compared to the standard Switch's 6.2 inches. It also loses out on the HD rumble feedback that shakes the console when things happen in the game. Thankfully, you get more battery life and a lower price, which makes these compromises easier to take.

The standard Nintendo Switch was already an impressive piece of hardware, pumping out high-definition games despite being able to slip into a (fairly large) pocket. So how has Nintendo managed to slim this tech down even more – and boost the battery life at the same time? We decided to take a look inside to find out.

© Nintendo

There are three colours to choose from, along with some special editions

Display
Here sits the Switch Lite's 5.5-inch LCD screen. It has a resolution of 1,280x720, like the original.

D-pad
This small cross pad is big news for Switch fans. The original console had four buttons instead of this preferred setup.

Buttons
These buttons press down to engage sensors on the board underneath. It's the same kind of tech Nintendo has used for years.

Shoulder buttons
Nintendo has redesigned the pressure sensor under the shoulder button – making them feel nicer under your fingers.

Main board
This board houses all the chips that power the Switch Lite, including a more efficient custom Tegra processor.

The Switch Lite's updated shoulder button (left), compared to the standard Switch (right)

© iFixit

"The controllers are built in as part of the console itself"

How does the Nintendo Switch Lite work?

Discover the tech behind the new, smaller games console

Rear casing
The Switch Lite loses the kickstand that let you play using wireless controllers, but gains a nicely-rounded rear case.

Metal cover
This metal plate helps spread the heat that's created by the chip across the whole console.

Fan
The Switch Lite's fan is smaller than the one in the standard Switch – because the Tegra chip creates less heat.

Battery
This Switch uses a 13.6 Wh battery. That's smaller than the old Switch, but still lasts longer thanks to that efficient Tegra chip.

Speakers
These two speakers fit into the two sides (the controller areas) of the console, to offer better audio performance.

The Switch's best portable games

The Switch has been in the wild for almost three years and is backed up by a large library of excellent games. Leading the pack are big names like Zelda, Mario and Pokémon, but there are also hundreds of fantastic third-party titles (from big publishing companies like Ubisoft and Microsoft) and indie games (made by small, independent studios). The biggest sellers have all come out of Nintendo's own studios – titles like *Mario Kart 8 Deluxe*, *Super Smash Bros. Ultimate* and *Pokémon Let's Go* – but you'll also find the likes of *Minecraft*, *Crash Bandicoot* and *Stardew Valley* on that list. And with so many indie developers bringing their games to the Switch (in some cases, as Switch exclusives), it's easy to see why it's been such a big hit with gamers looking for a great mix of triple-A titles and smaller adventures to play wherever they go.

Hammocks may also join seesaws as a way for humans to create additional energy at the base

Cutting carbon levels with artificial trees

These man-made trees could offset the emissions of the growing human population

Every day the human population expands, taking up more space and increasing our demand for natural resources. Not only are we consuming more, but the increasing by-products of our lifestyles can be a threat to the environment. Just by breathing – an essential part of living – we are producing an increasing volume of carbon dioxide.

Trees and animals create a fine balancing act with the planet's atmosphere. We rely on the world's forests to respire and absorb large quantities of carbon dioxide that humans and animals release. Plants use this process to produce their own energy.

This system works for now, but what happens in today's world when the human population is skyrocketing, polluting the atmosphere with fossil fuels while forests diminish? If this trend persists, the balance will be upset. Global warming will see extreme weather conditions, warming seas, acid rain and the extinction of thousands of species. Human activity has contributed to the highest carbon dioxide levels for 800,000 years. So can we assist the planet in reducing our impact on the atmosphere?

One option being explored is to replace the trees being cut down with artificial trees. These are being manufactured for Boston, in the US by the Lenfest Center for Sustainable Energy at Columbia University, to emulate the air-transforming ability of plants. We can't make existing trees work overtime, so why not make our own?

> *"Doing the job of trees but at rates 1,000 times quicker"*

Powered using the Sun's energy at the top and kinetic energy at the base, these plastic treepods can filter out the damaging levels of carbon in the air around them. In a process called the 'humidity swing', they absorb carbon dioxide and release breathable oxygen, doing the job of trees but at rates 1,000 times quicker.

These intriguing fake trees will also take advantage of visits from the public. While visitors play on the seesaws built below, the kinetic energy they produce from this activity will actually help the artificial trees to perform their vital task.

Designing the treepods

The job of turning carbon dioxide into oxygen is being carried out in nature by the 60,000 species of tree known in the world. With this in mind, which one of these specially evolved organisms informed the treepod's design?

The species chosen as the basis for the Boston Treepod's shape is the dragon blood tree. These trees have several beneficial properties: they have wide branches to allow larger quantities of resin through the extensions, and inbuilt filtering systems.

The dragon blood tree's top-heavy build is also replicated in the design. The treepod's umbrella-shaped appearance mean that they can support sizable solar panels. The ultimate aim was to create the most efficient system in the best use of space. With the greatest possible surface area enabling sunlight absorption, less energy will be required by seesaw riders. This combined use of space for energy efficiency and air filtering means that just one treepod is the equivalent of 1,000 real trees.

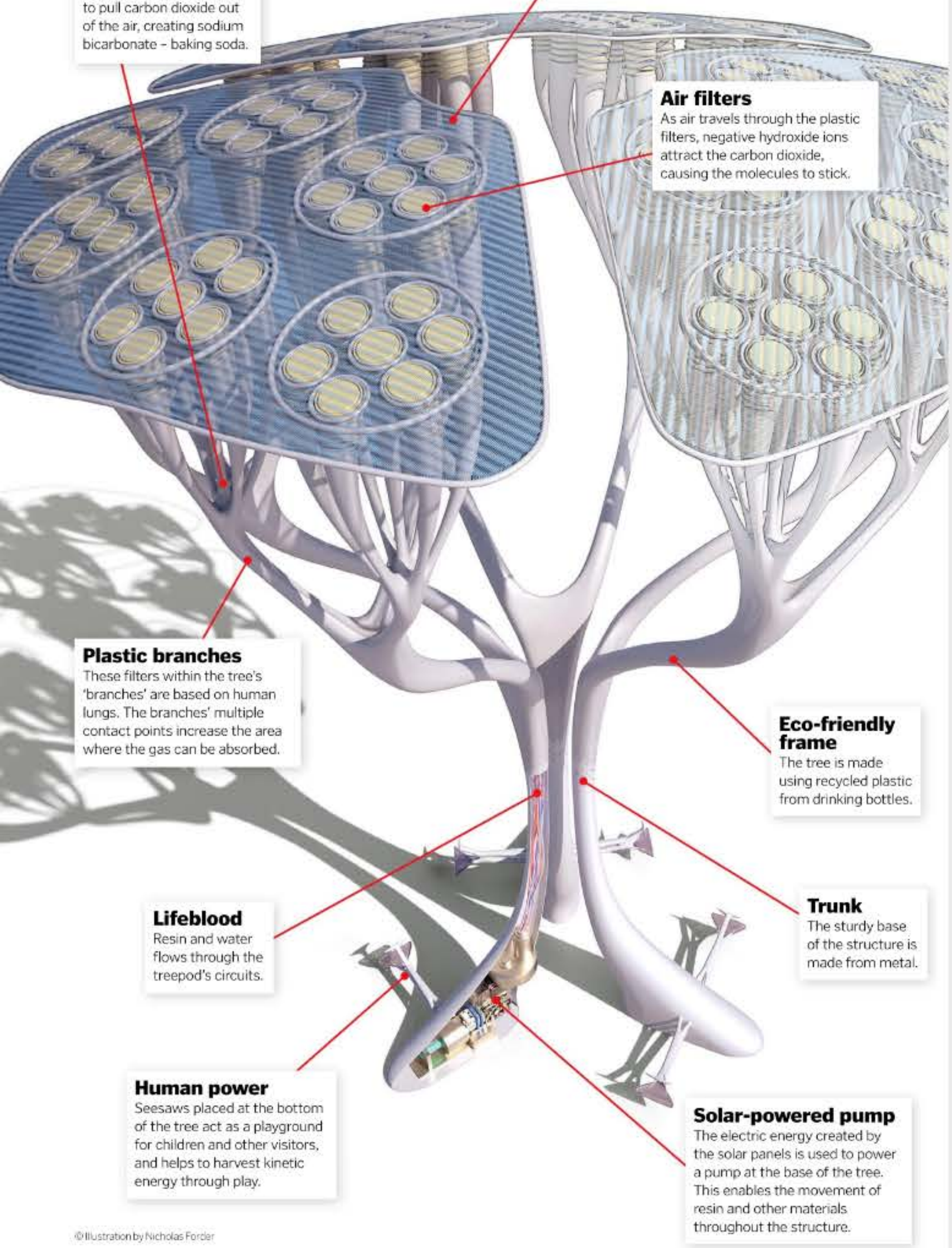
The trees are inspired by dragon blood trees. Their shape helps to absorb as much sunlight as possible

© Getty

AR ZONE! SCAN HERE

How fake trees filter

Discover the man-made machines with a natural purpose



Resin
The artificial resin combines with sodium carbonate, and this reacts to pull carbon dioxide out of the air, creating sodium bicarbonate – baking soda.

Solar panels
Like real trees, panels at the top will convert the sunlight to generate the required energy. Unlike plants, the converted energy is in the form of electricity.

Air filters
As air travels through the plastic filters, negative hydroxide ions attract the carbon dioxide, causing the molecules to stick.

Plastic branches
These filters within the tree's 'branches' are based on human lungs. The branches' multiple contact points increase the area where the gas can be absorbed.

Eco-friendly frame
The tree is made using recycled plastic from drinking bottles.

Lifeblood
Resin and water flows through the treepod's circuits.

Trunk
The sturdy base of the structure is made from metal.

Human power
Seesaws placed at the bottom of the tree act as a playground for children and other visitors, and helps to harvest kinetic energy through play.

Solar-powered pump
The electric energy created by the solar panels is used to power a pump at the base of the tree. This enables the movement of resin and other materials throughout the structure.

www.howitworksdaily.com

ONE THIRD

of fossil fuel emissions were removed by global forests between 1990 and 2007

20%

of the world's oxygen comes from the Amazon rainforest

CARBON DIOXIDE OBTAINED BY TREEPODS COULD BE USED FOR CLEAN-BURNING, CARBON-BASED FUELS

36 CARS

The number of cars' emissions one treepod could absorb each day

AROUND 10 MILLION ARTIFICIAL TREES WOULD ABSORB 12% OF THE CARBON DIOXIDE HUMANS PRODUCE EACH YEAR

18 PEOPLE

can live off the oxygen produced by 4,000 square metres of trees each year

How the world celebrates CHRISTMAS

From Ancient Egyptian festivals to current celebrations, how has history shaped Christmas around the globe?

Words by **Ailsa Harvey**

For many people, Christmas is the most magical time of the year. While modern Christmas traditions seem extremely commercial, aspects can be traced back to ancient roots. A huge variety of cultural customs have merged together in modern times, with the rise of the internet and travel enabling diverse celebrations to be shared and adopted. Singing, decorating and eating specific meals can be observed in many areas of the globe. But each country still holds onto their ancestors' festive ways to keep traditions alive.

Lighting up the coldest and gloomiest months of the year has been a common theme across thousands of years of civilisation. How has history forged the Christmas of today? Here's how Christmas has become a time where we indulge in festive foods, drag pine-shedding trees into our homes, light up the streets and send little cards to the people we know.

Christmas through the ages

Christmas celebrations have radically changed over the years

1520 BCE

Ancient Egyptian festivals

Ancient Egyptians celebrate the birth of Horus, the son of the gods Isis and Osiris, during a festival on 25 December. This is the first record of this date being celebrated. Festivities involve large banquets, the burning of lamps and decorating homes with green palm leaves.

Source: Wikimedia Commons

Egyptian artwork shows gifts being offered to the son of Isis

497 BCE

Roman Saturnalia

In early winter the Romans celebrate the Saturnalia festival, honouring Saturn, the god of agriculture. Feasts take place, and livestock is slaughtered before the winter and eaten. These celebrations continue from the end of December through to the beginning of January.

© Getty

A painting portraying an extravagant Roman feast during Saturnalia

336 CE

Celebrating the 25th

This is the earliest official record of 25 December being a celebration of Jesus's birth. For the first three centuries of the millennium his birthday isn't celebrated, and Easter is seen as the holier day by the early Christians.

1298

Early Christmas markets

Vienna's Christmas markets in the Middle Ages display similar scenes to the Christmas markets seen around Europe and elsewhere today. In these early markets, citizens are given permission to hold the stalls during Advent, in the run-up to Christmas Day.

© Getty

While early Christmas markets lasted a couple of days, today's markets last for up to a month

1500s

Tudor pies

On the 12th night of Christmas, Tudor households bake a fruitcake to be shared with guests. This isn't just a dessert, but an opportunity to become 'king' or 'queen' for the rest of the night's celebrations. A coin or dried bean is hidden inside the cake, and whoever receives it wins the title.

© Getty

Cakes had a coin or bean hidden among the pieces of fruit for someone to discover

1549

Introducing Japan to Christmas

St Francis Xavier arrives in Japan in 1549 and attempts to bring Christianity to the country. A few years later the first Christmas celebrations take place in there. In modern times, festive decorations line most streets in Japan at Christmas time.

© Getty

A statue of St Francis stands in the city of Hirado, Japan

1550-1600s

Elizabethan Christmas

An important part of an Elizabethan Christmas is the food. It is an opportunity to demonstrate a family's wealth to numerous guests and friends. Roasted peacock and swan are the ultimate birds of choice in these extravagant Christmas feasts. Poorer members of the community are often invited.

© Getty

Carol singing and dancing were popular activities during Elizabethan Christmas celebrations

1700-1800s

12th night parties

After the revival of Christmas in England, parties are back in full swing. The 12th night (5 January) had been celebrated since the Middle Ages, but the games, food and drink become even more popular with people during this time period.

1822

Twas the night before Christmas

Clement Moore writes *A Visit From St Nicholas*, more often known as *Twas The Night Before Christmas*. This poem has remained popular, starting an annual tradition for many families to read it on Christmas Eve.

Source: Wikimedia Commons

Clement Moore's handwritten manuscript

1843

The first Christmas cards

The Victorians start the tradition of sending Christmas cards. The first ever is believed to have been designed and printed in England by John Callcott Horsley. In 1846, 1,000 cards with the first card's design are sold for a shilling each.

© Getty

The design on the first ever Christmas card

1847

Creating the cracker

Confectioner Tom Smith invents the Christmas cracker, inspired by a French sweet wrapped in paper twisted at both ends. With the aim of beating his competitors in sales, he also adds a motto inside, then replaces the sweet with a gift. In 1860 the 'bang' is added.

© Getty

It was Tom Smith's son who invented the paper hat now found in most crackers

800 CE

Viking Yule

The Vikings celebrate a period of 12 days, beginning on 21 December. Referred to as 'Yule', this period involves drinking, feasting, banquets, games, song and a sacrifice to the gods. The evergreen tree, which we now also know as the Christmas tree, is used as a symbol of life for the Vikings, who decorate them with gifts and carvings to encourage the spirits of all plants to return in the spring.

Source: Wikimedia Commons

Artwork depicting a Yule sacrifice

934

The fear of Odin

King of the Norse gods, Odin flies over towns during Yule to decide who will prosper and who will perish. King Haakon I brings Christianity to Norway, aligning old pagan beliefs with the dates of Christian festivals.

© Getty

Some believe that Santa Claus could have been inspired by the traits of Norse god Odin

1038

Medieval fasting

During this time there are the first mentions of people fasting until Christmas Eve. Fasting before Christmas provides a good excuse for a large-scale feast when Christmas finally comes around.

Middle Ages

Presents for peasants

On Boxing Day, the poor go to the houses of the rich and ask for food and drink. During Christmas time it becomes an opportunity for the upper class to repay society by providing for the less fortunate. Christmas Day isn't as pleasant as it may sound for the less wealthy, as the day often coincides with 'quarter day' – one of four days of the year when rent is due, and poorer tenants struggle to pay.

1644

Cancelling Christmas

The English Parliament bans all Christmas celebrations. The puritans believe that some of the celebrations taking place – such as excessive drinking and eating – are unnecessary and don't reflect the true meaning of Christmas. Under Oliver Cromwell's reign, Christmas involves only fasting and prayer.

1659-1681

America loses Christmas

The puritan ban on Christmas celebrations and festivities soon spreads to the English colonies in America. Showing any sort of Christmas spirit in Boston comes with a hefty penalty of five shillings (the equivalent of around a £25 fine today).

1660

Christmas returns to Britain

Following the death of Oliver Cromwell, Charles II is restored to the throne. This news is joyfully received by the public as it means the return of Christmas and the freedom to celebrate once again, as the strict puritan laws are overturned.

1752

A new New Year

Most of us are used to celebrating the end of the Christmas season on New Year's Day on 1 January. Before 1752, however, New Year's Day was celebrated on 25 March. As a result 1751 is a short year in the calendar, only running from 25 March to 31 December as the start of the new year changes to 1 January.

© Getty

Fireworks on New Year's Day originate from ancient belief that noise will scare away evil spirits and bring about good luck

Early 1900s

More presents

The start of the 20th century sees an increase in gift-giving, as manufacturers and shops begin to fully explore the commercial possibilities of the festive season, encouraging people to buy presents for each other as a symbol of the Christmas spirit.

© Getty

Children choosing their Christmas toys in Oxford Street in London, 1932

1904

Advent calendars

The idea of today's advent calendars comes from a German man named Gerhard Lang. He takes inspiration from his mother, who would count down to Christmas with him as a child by giving him baked meringue treats to soothe his impatience. As an adult, Lang works to improve his design, resulting in the chocolate calendars that are still popular today.

Source: Wikimedia Commons

An Advent calendar from 1910, designed by Gerhard Lang

1914

Christmas truce

In World War I, enemy forces put aside their differences for one night only, to demonstrate the influence of the Christmas spirit. When British soldiers hear the German opposition singing Christmas carols in their trenches during the Christmas of 1914, the two sides stop fighting and meet in no-man's land to exchange gifts and play games together.

Source: Wikimedia Commons

Soldiers in World War I play football together to celebrate Christmas Day

1940

Christmas Blitz

After London had been bombed for 57 consecutive nights by German aircraft and with Christmas Day drawing closer, many people in the city spend Christmas Eve in the less homely setting of an air raid shelter. Many continue to celebrate Christmas from there.

© Getty

A group of boys continue to celebrate Christmas in an air raid shelter

Today's Christmas traditions

Take a journey around the world and discover some countries' unique festivities

GERMANY

St Nicholas Day

Christmas Eve is a bigger celebration in German households than Christmas Day itself. Gifts are given on Christmas Eve and a large meal is eaten. German children write letters to St Nicholas rather than Santa Claus, and St Nicholas Day is celebrated on 6 December.

In Germany, Poland and Ukraine, finding a spider or spider's web on your Christmas tree is considered good luck

© Getty

ICELAND

Christmas trolls

Icelandic folklore provides not one Santa but 13, who come down from the mountains. Children in Iceland place a shoe at their bedroom windows every evening in the 13 days leading up to Christmas Day; one night for each 'Yule lad'. The children wake up to various sweets and treats from each troll character – or maybe a rotting potato, depending on how they behaved during the day.

© Getty

NORWAY

Hide the brooms

Norwegian tradition has it that Christmas Eve is the time when evil spirits and witches arrive in the towns. Before going to sleep on the night before Christmas, some people still hide any brooms in their houses. This is so they don't attract witches.

© Getty

UNITED KINGDOM

The Queen's speech

Amid the Christmas celebrations in the UK, millions of people turn on their televisions to hear from the queen. In her annual speech, she talks about the big events in the year and gives her thoughts. Her first televised Christmas speech was in 1957, and her speeches have been broadcast every year except 1969, when she believed the royal family had been on TV enough.

Queen Elizabeth II posing for a photo after completing her 2018 Christmas speech

© Getty

AUSTRIA

Krampus: festive fear

In Austria not all Christmas characters are as pleasant as Santa Claus. As well as accepting St Nicholas, who rewards the good, Austria has adopted an evil character to instil fear and punishment. Krampus is a half-goat and half-human being who roams the streets searching for badly behaved children. His horns and fangs give them a reason to be good, and many enjoy fleeing from the character as he emerges on Krampus night, 5 December.

© Getty

ITALY

12 courses of Christmas

An old Christmas tradition throughout Italy is to fast throughout Christmas Eve in preparation for a huge multi-course Christmas meal. While rules are more relaxed today, tables are traditionally set for either nine, 12, 13 or even 21 courses. These numbers are all of varying religious significance, with nine courses for the trinity (squared), 12 presenting a course for each of the apostles, and 13 for the disciples. The monster 21-course meal is designed to represent the trinity multiplied by the seven sacraments.

© Getty

AUSTRALIA

A white-hot Christmas

In contrast to the white Christmases portrayed in many Christmas films, Australians celebrate in the scorching summer heat. Some decorate their houses with bunches of 'Christmas bush', a native Australian tree with green leaves and cream flowers.

Christmas Day down-under is usually spent doing outdoor activities, such as having a barbecue on the beach

© Getty

PHILIPPINES

Giant lantern festivals

The Philippines' Christmas festivities last for an impressive four months. When December arrives, flamboyant six-metre-tall lanterns are made. These decorations contain thousands of light bulbs and are put on display as part of a competition and festive exhibit, for all to enjoy.

Source: Wikimedia Commons

GHANA

End-of-harvest rest

Ghana is one of the countries in Africa that celebrates the Christmas season. For many in the country, the holiday begins on the first day of the month and coincides with the end of the cocoa harvest for a well-earned celebration. Neighbourhoods can be seen embellished with candles and sparkle for four weeks until Christmas Day arrives. Their Christmas Day meal is often soup, goat and vegetables.

A typical Christmas meal in Ghana involves okra soup, rice and yam paste called 'fufu', which is pounded in a bowl

Source: Wikimedia Commons

ROMANIA

Ignat Day

Romania's Christmas meals commonly involve eating pork, but that isn't where the tradition ends. Romanian families who keep pigs have continued the ritual of killing one of them before Christmas Day. This stems back to the time when families' pigs wouldn't survive cold winters.

A Romanian pig marked with blue paint on its last day before sacrifice, on the traditional day of Ignat

© Getty

5 FACTS ABOUT EARLY CHRISTMAS DECORATIONS

1 Baubles
The first glass Christmas tree ornaments were made by glassblower Hans Greiner in the 16th century as he couldn't afford to decorate with real apples.

2 Tinsel
Tinsel was introduced to Christmas in 1610. The original decorations were arguably more impressive as they were made of strands of pure silver.

3 Candy canes
The invention of candy canes dates back to 1670, when a choirmaster provided the treats to choir boys with the aim of keeping them quiet throughout a ceremony. Their design is based on traditional shepherds' sticks.

4 Christmas trees
Christmas trees are believed to have been used to celebrate winter for around 1,000 years. Throughout winter, the fir tree branches were used to remind people that spring would be next to arrive.

5 Christmas lights
The first electric Christmas tree lights were invented in 1895, as the candles that were previously being used were causing too many fires.

St Nicholas shown saving three innocent boys from a butcher's barrel


Today, St Nicholas is celebrated on the anniversary of his death, 6 December

© Getty

A life's work

Though most of St Nicholas's life isn't documented, known dates are honoured and celebrated

270 CE
Nicholas is born in Patara in Asia Minor, today part of Turkey.

317 CE
St Nicholas becomes the bishop of Myra. Many stories start to arise about him caring for others, providing homes, hospitals and inns.

325 CE
Nicholas attends the Council of Nicaea to defend his religion. A debate about the Holy Trinity reportedly gets heated and violent.

6 December 343 CE
St Nicholas dies. He is buried in his church in Myra.

St Nicholas of Myra

Discover why one man's life has been honoured for centuries, and how he has shaped the spirit of Christmas

Today the mention of St Nicholas sparks excitement in children as they anticipate presents, but where did this figure originate from? The character who is widely commemorated at this time of year has undergone several transformations and been known by a variety of names over the centuries, but the real St Nicholas of Myra is a celebrated hero of the past, whose legacy can be traced back to the year 270 CE.

Nicholas was born in Patara, which is now part of modern-day Turkey, to wealthy Christian parents. They dedicated their son to God, and it is said that Nicholas started reading sacred books at the age of just five years old. Although he suffered the loss of his parents at a young age, Nicholas chose to care for others and assist those who were even less fortunate than himself.

Nicholas was a dedicated Christian, and his religious convictions and care for others resulted in him being made the bishop of Myra. Throughout his time as bishop, and at other stages in his life, there are stories of Nicholas going out of his way to provide for children and those who have been dealt an unfortunate hand in life – acting as saviour when freak accidents struck and always standing up for what he believed to be correct.

Sticking to his morals and beliefs sometimes led him into trouble, notably during the time when Nicholas was imprisoned under the rule of Roman Emperor Diocletian. At this time, all who followed Christianity were persecuted, and his time in prison was spent surrounded by other bishops, priests and staunch followers of the Christian faith.

After his death, a watery liquid called manna began to form in Nicholas's grave. It was believed that the water had healing powers, and the site soon became a memorial to the saint.

Having been a recognised saint across much of Europe, in the 1500s things started to change. The practice of honouring saints began to diminish in many countries, but his memory was kept alive in some places, and immigrants later spread the stories around the world.

> *"Around Christmas time, variations of his stories are told, encouraging people to emulate his charitable traits"*

While some of the stories of St Nicholas have been told and retold over centuries, enabling imaginative details to be twisted and added, it is believed that the core morals of these legends depict the true character of the man and saint who was St Nicholas of Myra.

Around Christmas time, variations of his stories are still told, encouraging people to emulate his charitable traits.

THE BIG IDEA

How St Nicholas became a symbol of gift-giving

The stories of St Nicholas protecting children and sailors, among others, show the saint providing for people. This could be the literal gift of money, or simply enhancing the lives of those in need. As these stories were told around the world, recognition of him spread to a number of countries, including Russia and Greece, where he became a patron saint.

While honouring saints became less common, his legacy continued to be celebrated in the Netherlands. There, the feast day of St Nicholas also incorporated the tradition of children leaving their shoes outside the night before the feast, in the hope that the man in the stories, who'd brought so much joy to others in the past, could do something similar for them. Today the tradition of St Nicholas bringing gifts to children continues in the Netherlands, as well as many other countries, where he has transformed into the character of Santa Claus.

A German illustration from 1910 shows the similarities between St Nicholas and Santa Claus

FIVE LEGENDS ABOUT... ST NICHOLAS'S MIRACLES

1 Nicholas's first miracle
This is said to have occurred when, as a boy, he came across a woman with a deformed hand. Placing his hands on hers and saying a prayer, the hand became whole again.

2 Butchered boys
A butcher invited three poor boys into his home during a famine. The man killed them with his tools. St Nicholas heard this story from an angel and went to bring the boys back to life.

3 Sailor's protector
During his pilgrimage to the Holy Land as a young man, Nicholas is thought to have tamed a dangerous storm, saving many sailors. It was this event that led to him becoming a bishop.

4 Freed of the famine
When Myra had a famine, Nicholas appeared in the dream of an Italian grain merchant. The merchant awoke holding gold coins. Obeying the message in the dream, he took grain to Myra.

5 Protecting the poor
Nicholas saved three daughters who couldn't afford marriage. To stop them being sold to men and entering what he deemed a life of sin, St Nicholas tossed bags of gold through an open window.

'The Awakening of Father Christmas' from the popular satire magazine, Punch, in 1891

Source: Wiki / John Tenniel

1100s
French nuns begin giving chocolate to children on 6 December – known as 'Feast Day'. Today this date remains a day to celebrate St Nicholas in many countries.

1087
Sailors from Bari, modern Italy, remove half of Nicholas's body from his grave to take to their city. They build a major basilica dedicated to the saint.

1700s
St Nicholas inspires the creation of Santa Claus. Dutch immigrants spread the tale of Sinterklaas to America, where he soon becomes Santa Claus.

DID YOU KNOW? *Around 23,000 individuals in the UK currently have diplomatic immunity*

What is diplomatic immunity?

Discover how this blanket protection is supposed to help prevent international incidents

The rule of law means that no one is above the law – unless you're a diplomat. As servants to their state countries, diplomatic agents are government officials, envoys (messengers) and ministers that journey around the world in their country's national interest, negotiating treaties and developing economic relations between their home and host countries.

In the US, presidents are given diplomatic passports for life

In this pursuit of peace between two nations, the job comes with protection from the laws of a foreign power: this is called diplomatic immunity. The level of protection varies based on a diplomat's rank. The highest is an ambassador, who is protected against any arrest, prosecution or order to testify in court – for anything from parking fines right up to murder. It's a privilege that's also extended to the diplomat's family.

The purpose of this blanket protection for diplomatic agents abroad is to prevent cases of false imprisonment, conspiracy and even torture as political retaliation. There are exceptions to the rule, and if an envoy is believed to have truly committed a crime, host countries can appeal to an envoy's home nation to waive immunity. The host nation can also expel the individual from the country, branding them 'persona non grata', meaning 'unwelcome person'. This is what American President Barack Obama did in 2016, giving 35 Russian government officials 72 hours to leave the country in retaliation for election hacking.

This modern-day form of international protection was first outlined in the Vienna Convention on Diplomatic Relations in 1961, and has since been ratified by 192 countries. However, protection for official messengers abroad has been around since ancient times. For example, when Rome sought alliances with neighbouring states, visiting Roman envoys known as nuntii were afforded inviolability.

Diplomacy around the world

Ten countries with the most diplomatic presence abroad

UNITED STATES OF AMERICA (273)
Embassies 167
Consulates 90
Permanent missions 9
Other representation 7

TURKEY (229)
Embassies 134
Consulates 81
Permanent missions 12
Other representation 2

CHINA (268)
Embassies 166
Consulates 90
Permanent missions 8
Other representation 4

UNITED KINGDOM (225)
Embassies 149
Consulates 55
Permanent missions 9
Other representation 12

FRANCE (266)
Embassies 160
Consulates 89
Permanent missions 15
Other representation 2

GERMANY (224)
Embassies 149
Consulates 61
Permanent missions 12
Other representation 2

RUSSIAN FEDERATION (242)
Embassies 143
Consulates 87
Permanent missions 10
Other representation 2

BRAZIL (221)
Embassies 137
Consulates 70
Permanent missions 12
Other representation 2

JAPAN (229)
Embassies 144
Consulates 62
Permanent missions 9
Other representation 14

SPAIN (215)
Embassies 115
Consulates 89
Permanent missions 10
Other representation 1

EMBASSY/HIGH COMMISSION
Typically positioned in a country's capital city, an embassy is the official residence and office of an ambassador.

CONSULATE
Usually found in a tourist city, a consulate is the residence and office of a consul, tasked with protecting people abroad.

PERMANENT MISSION
A mission can be found in a country where an international organisation, such as NATO and the European Union, is based.

OTHER REPRESENTATION
A representative office is located in a country where there is no formal diplomatic relationship.

Lowy Institute Global Diplomacy Index 2017

© Getty

The man in the diplomatic bag

In the Vienna Convention it states that "The official correspondence of the mission shall be inviolable. Official correspondence means all correspondence relating to the mission and its functions. The diplomatic bag shall not be opened or detained." This allows diplomats to carry or send classified information between their home and foreign nations with protection from the eyes of border customs officers.

Although the Vienna Convention also states that the diplomatic bag should "contain only diplomatic documents or articles intended for official use," past diplomats have exploited this protective policy to conduct criminal activity, in the process risking diplomatic relations between the two countries. For example, in 1984 the former Nigerian minister Umaru Dikko had been accused of stealing around £625 million of Nigerian government money. Fleeing to London, he was kidnapped by Nigerian and Israeli officials and placed in a crate, along with a doctor who had sedated him, set to be taken back to Nigeria.

However, a customs officer made the connection between the shipment and a recent kidnapping report. Having noticed that the crate was not correctly marked as a diplomatic bag, the immunity was waived and opened, revealing the human cargo within.


© Shutterstock

Umaru Dikko was being taken into an aeroplane's cargo hold when police lifted the lid on his 'diplomatic bag' prison

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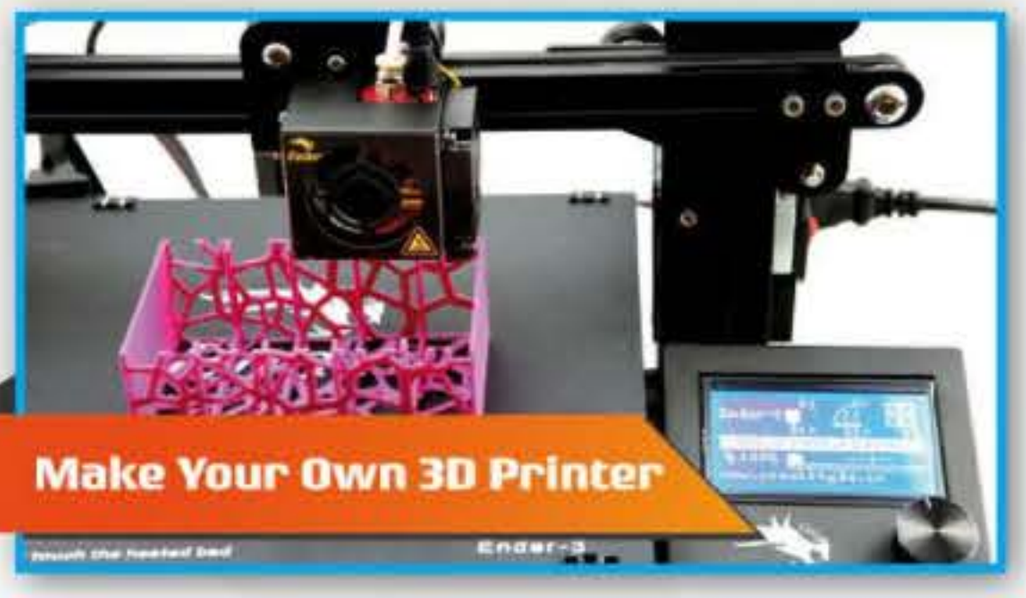

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Inside a navy landing ship

How It Works boards RFA Lyme Bay to discover the ways this Swiss army knife of ships supports fighting forces and disaster relief efforts around the world

Behind every good Royal Navy vessel is a great Royal Fleet Auxiliary ship, and RFA Lyme Bay is no exception. As a member of the Royal Fleet Auxiliary (RFA), Lyme Bay is manned by uniformed civilian merchant sailors and is a branch of the naval services, supporting Royal Navy military operations across the globe. This vessel assists in anything from war-fighting missions and law enforcement to disaster relief and evacuations.

As part of the Landing Ship Dock Auxiliary (LSDA), Lyme Bay is often referred to as the 'swiss army knife of ships'. This 16,160-ton vessel is more than just a transport ship, and it has a whole host of tricks up its sleeve to serve the navy or those in need.

Stepping aboard this 177-metre long vessel, it quickly becomes apparent that Lyme Bay is built with adaptability and hospitality in mind. As we moved through its interior maze of corridors and staircases, it came as no surprise to see the usual

RFA Lyme Bay has been operational since 2007

elements of a navy vessel, such as the bridge, engine control room and communication centre. However, with the vessel's fully equipped gym and extensive dining hall, it's easy to see why Lyme Bay is such a valuable asset for transporting both military personnel and civilians across the waves. Capable of holding around 450 troops or up to around 1,000 evacuees, this floating behemoth is one of three Bay class-ships that are vital to evacuation and military deployment missions.

People aren't the only passengers Lyme Bay can accommodate within its hull. In the bowels of the ship is a vehicle level that spans almost the entire length of the ship. This cavernous holding deck houses military vehicles such as track layers, diggers, helicopters and amphibious vessels, for transportation to shore or the sea around the globe. Lyme Bay also has a flight deck for helicopters to land and take off from.

As a support vessel, Lyme Bay is also capable of generating energy and clean water. Using a diesel-electric propulsion system, diesel engines placed on either side of the ship's stern are connected to four electricity generators, which can produce around 12 megawatts of energy. Stored excess energy can be siphoned off to those that need it. Clean water is another commodity this vessel can offer, thanks to reverse-osmosis pumps and salt filters. These can take surrounding ocean water and produce around 120 tons of fresh water a day.

"This 16,160-ton vessel is more than just a transport ship, and it has a whole host of tricks up its sleeve to serve the navy"

Members of the Royal Fleet Auxiliary

Primary Casualty Receiving Facility (PCRF)
RFA Argus (A135)
The only operational PCRF ship, RFA Argus houses a 100-bed medical complex, with an emergency department, surgical facilities and radiology suite, including a CT scanner.

Landing Ship Dock Auxiliary (LSDA)
RFA Mounts Bay (L3008)
These support vessels, including RFA Lyme Bay and Mounts Bay, provide logistical support for amphibious operations by transporting and delivering troops and supplies across the world.

Fleet Solid Support Ships (FSSS)
RFA Fort Victoria (A387)
One of the main responsibilities of ships like RFA Fort Victoria is to provide and replenish stores and resources (food, fuel, etc.) to other Royal Navy vessels.

Tankers
RFA Tidesurge (A138)
One of 4 Tide Class tankers new to the RFA, which includes sister ships Tidespring, Tiderace and Tideforce; these state-of-the art vessels deliver fuel, water and stores to Royal Navy ships globally.

AR ZONE!

Coming to the rescue

One of the many roles of the Bay-class ships is to not only offer support to other navy vessels at sea but to act independently to provide relief to those in need. For example, in October 2015 RFA Lyme Bay and its civilian crew sailed over to the Bahamas after the category 4 Hurricane Joaquin devastated a remote community on Crooked Island.

Home to around 350 people at the time, Crooked Island residents required Lyme Bay and its humanitarian passengers to deliver fresh supplies, such as water and aid, to islanders ashore.

The beach

Arguably Lyme Bay's crowning glory is its ability to allow other vessels to sail straight into the bowels of the ship. Known as 'the beach' to those aboard, the rear door of Lyme Bay can be lowered while at sea to enable vessels such as mexeflotes (small landing craft for transporting goods) to move straight into the ship's vehicle deck.

To do this, Lyme Bay has to submerge its stern (rear) by three metres, flooding the back opening. This process of self-sinking is called controlled ballasting, whereby pumps expel stored seawater from ballast tanks into the stern to lower that end of the ship. The water is pumped back out to raise it again.

For the Lyme Bay this process can take up to four hours, but once the ship is lowered it can travel without the immediate need to close its back door.

© Alamy

Vessels can be launched out into open water through the ship's rear door while at sea

Inside Lyme Bay

Take a glimpse into the stomach of the ship

AR ZONE! SCAN HERE

Flight deck
Recognisable as a landing ship, Lyme Bay can also support a mobile aircraft hanger for long-duration travel.

Azimuth thrusters
Capable of 360-degree rotation, these powerful thrusters provide quick manoeuvrability and a top speed of around 18 knots (around 33 kilometres per hour).

Well dock
This is the entry and exit point for vessels aboard the Lyme Bay – also known as 'the beach'.

© Alamy

Bay-class ships like Lyme Bay are able to launch other vessels from within

Cranes
In order to move vehicles and supplies from land, Lyme Bay has two 30-ton cranes on its flight deck to do the heavy lifting.

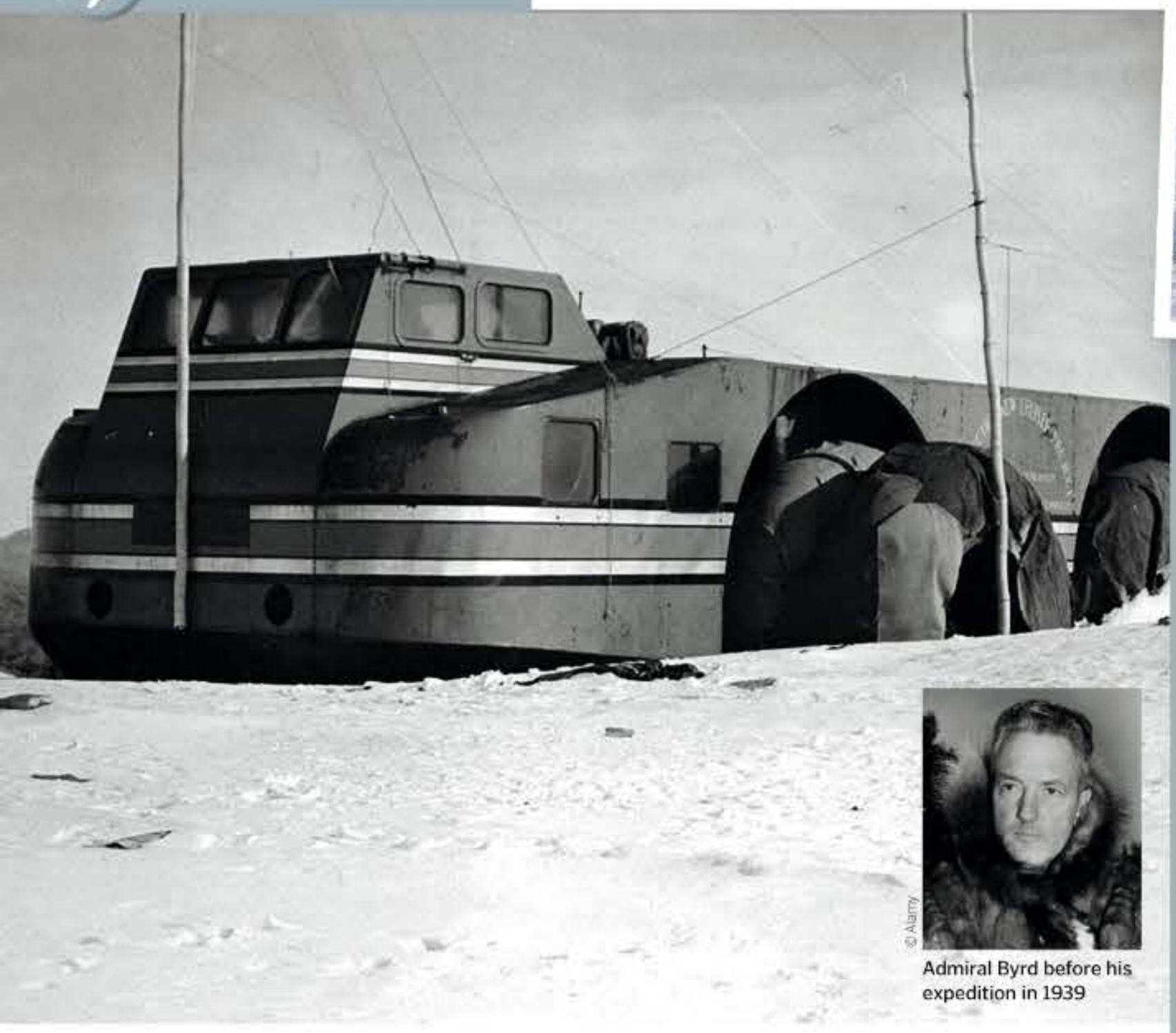
Accommodation
With the ability to hold up to around 450 troops, this ship is also able to store enough food to last for 48 days at sea.

Lift
One particularly impressive feature of this ship is the 20-ton lift that connects the flight and vehicle decks. It enables crew members to move vehicles within the vessel.

Vehicle deck
This is where the majority of vehicle and supply stores are held, along with the flight deck.

Safety
In the event of an emergency, Lyme Bay is equipped with lifeboats as well as a Mass Evacuation System (MES), which inflates tubular slides for crew to safely evacuate the ship into life rafts.

RFA Lyme Bay can lift vehicles and vessels with ease off its flight deck and onto the ground or into the ocean



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Admiral Byrd before his expedition in 1939

This Sno-Cat shows how belts rather than tyres spread weight more evenly on snowy surfaces

Enhanced explorers

Over a century has passed since the first Antarctic mission, and there is still so much to explore. Modern-day vehicles have acquired advanced technology that allows an easier transition onto the ice.

Compared to the heavy snow cruiser, today's vehicles are much more compact and lightweight. Modern technology means that vehicles can plan the least dangerous routes to take using GPS and a ground-penetrating radar system. While the cruiser was driving in completely unknown territory, today's radars assess the composition of the ground ahead of the vehicle, so they are less likely to become stuck or stranded.

Unlike Byrd's snow cruiser (see below), most modern Antarctic vehicles have belts rather than tyres, which are more suited to the terrain. Tyre-based vehicles struggle to gain traction on the softer snow, and can sink.

Admiral Byrd's Antarctic Explorer

Words by **Ailsa Harvey**

How did the much-anticipated, 20th century snow cruiser fare in this challenging continent?

Antarctica has been a key scientific research site for centuries. With its vast uninhabited frozen sheet, its conditions make exploration a challenge. However, this has not deterred people from trying.

In 1939, a group of American scientists and engineers chose to focus on this frozen land. Before they could set foot there, they needed the right equipment. For this trip, a monster vehicle was born. Construction was led by Thomas Poulter for the polar explorer Admiral Richard Byrd. Byrd's fourth Antarctic expedition was his most ambitious, as well as the largest.

The scientists would be taken to a playground full of scientific study. What was beneath the ice? Or in the sky? How did the weather compare? The need for both laboratory space and accommodation for several scientists contributed to the size of the cruiser.

Released from its construction bay on 24 October 1939, a 32-kilometre long traffic queue snaked through Chicago as people stopped to observe the cruiser. It was a cross between a bus and a tank: the vehicle was designed to hold all research equipment while tackling travel on the icy terrain. As if its arrival on the isolated Antarctic continent wasn't enough of an entrance, all this was to take place while carrying an entire aeroplane on its roof.

While travelling on roads between Chicago and Boston, a steering fault forced the vehicle into a stream, where it remained for three days. Though a shaky start, it seemed as though almost everything had been thought through and specifically built for Antarctica; from spare tyres in case of emergencies, to its bright red colour to aid visibility.

Hopes were high for Admiral Byrd and the explorers, but some of the cruiser's qualities ultimately let them down. The tyres were cleverly designed to account for a range of snow depth, but were too smooth to cruise through the snow on first contact. Tyres with no tread were believed to succeed best in these conditions, but this was not the case. In fact, better traction was found when driving backwards.

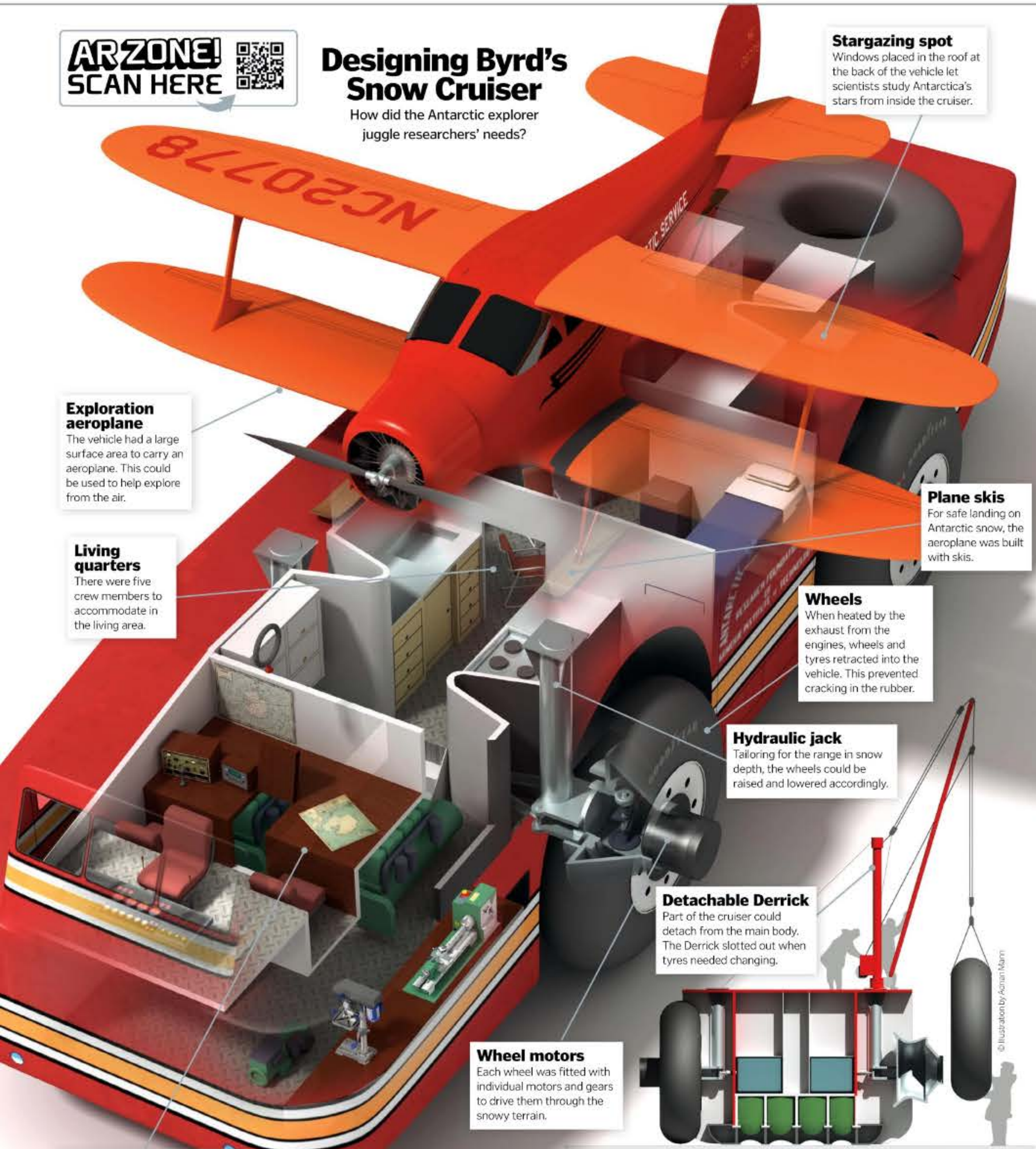
Devastatingly, the cruiser had to be abandoned, as its bulk and lack of manoeuvrability made it difficult to recover. Its exact whereabouts today are unknown.

One of the crew stands beside the cruiser's wheels, giving an idea of the vehicle's scale

AR ZONE! SCAN HERE

Designing Byrd's Snow Cruiser

How did the Antarctic explorer juggle researchers' needs?



Stargazing spot
Windows placed in the roof at the back of the vehicle let scientists study Antarctica's stars from inside the cruiser.

Exploration aeroplane
The vehicle had a large surface area to carry an aeroplane. This could be used to help explore from the air.

Plane skis
For safe landing on Antarctic snow, the aeroplane was built with skis.

Living quarters
There were five crew members to accommodate in the living area.

Wheels
When heated by the exhaust from the engines, wheels and tyres retracted into the vehicle. This prevented cracking in the rubber.

Hydraulic jack
Tailoring for the range in snow depth, the wheels could be raised and lowered accordingly.

Detachable Derrick
Part of the cruiser could detach from the main body. The Derrick slotted out when tyres needed changing.

Wheel motors
Each wheel was fitted with individual motors and gears to drive them through the snowy terrain.

Control cabin
With the operator seated at the front windows, the cruiser's systems were all controlled in this area.

ALIEN EVOLUTION

Life could arise from a variety of circumstances, but it all depends on what the host planet can offer

Words by **Lee Cavendish**

Alien life is something that everyone ponders at some point. It has allowed science fiction writers and film makers a creative licence, with actors and actresses dressed up in some very questionable attire. However, the truth is that there are so many variables when it comes to creating life, no one can say what alien organisms will look like. All that scientists can do is explore the possibilities.

A lot happened over 3.5 billion years for life to evolve on Earth, and it has all stemmed from the chemistry on this planet. The biochemistry of life here is based on carbon, with a water-based medium in our cells creating energy by metabolising oxygen. That is a simple way of describing the chemistry of life on our planet, and this is only the case because Earth has been gifted with this chemistry at a reasonable distance from the Sun. Over the last couple of decades, astronomers have found thousands of planets in different solar systems – known as exoplanets – that exist in a variety of conditions. So should we think that the chemistry of life is the same everywhere? There is definitely a strong argument to say otherwise.

For example, an exoplanet could exhibit life forms based on silicon instead of carbon. Silicon sits below carbon in the periodic table, meaning that it can form the same four bonds with other elements that carbon does. This forms similar long chains of molecules, or polymers. The difference between the two is that silicon has eight more electrons than carbon, which introduces a stronger repulsion factor and therefore makes silicon bonds weaker. The reason why diamonds are one of the strongest materials in the world is because of the way the carbon atoms are arranged.

However, silicon can prevail in more extreme temperatures. For example, silicon-oxygen bonds can withstand temperatures up to about 325 degrees Celsius. Carbon-oxygen bonds would not be able to exist in such conditions. So for exoplanets that orbit closer to their host star, silicon may be the answer.

Then there's the question of water. Earth is within the Sun's habitable zone, a region of space surrounding a star where temperatures are just right for liquid water to exist, which is thought to be vital in supporting life. But what about the exoplanets that aren't so lucky? Well, it doesn't have to be water that can provide a liquid medium in alien cells. Saturn's moon Titan is home to liquid bodies full of complex hydrocarbons methane and ethane. It has an intricate water cycle, similar to that of the Earth, which recycles liquid methane in a location far from the Sun.

Life has a way of adapting and overcoming extreme situations, as there are even signs of life on Earth that exist in the most inhospitable places. For example, in the depths of the ocean, far from the reach of sunlight, tube worms thrive without the need for light. These creatures create energy using the chemical-rich fluid from hydrothermal vents in a process called chemosynthesis. With all these possibilities and all the worlds in the cosmos, alternate alien evolution is entirely plausible.

The TRAPPIST-1 star has three planets – e, f and g – orbiting within the star's habitable zone

© NASA/JPL-Caltech

© Alamy

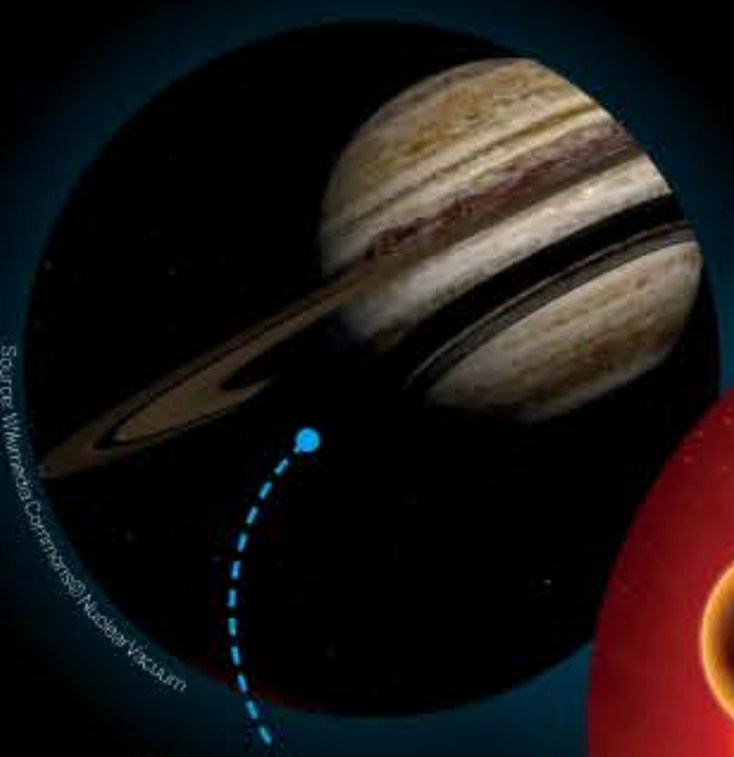
Earth's most indestructible life form

Tardigrades, also known as 'water bears', are eight-legged micro-animals that can thrive against the odds. They can survive just about anywhere, from mountaintops to the bottom of the ocean, and they are also capable of withstanding temperatures from -200 degrees Celsius to over 150 degrees Celsius.

These little creatures have been the subject of much investigation due to their indestructibility – even being launched into space. The results of these tests have shown that they can survive boiling liquids, radiation exposure, extreme pressures, and can be brought back to life after spending years in a dehydrated state; it's thought that only when the Sun dies will the tardigrades cease to exist. Their resilience means that they could also have the capability of existing on different worlds, encouraging the search for life on planets other than Earth.

Tardigrades prefer to live in moist environments like within sediment at the bottom of lakes

ALIEN PLANETS: THE TOP TARGETS

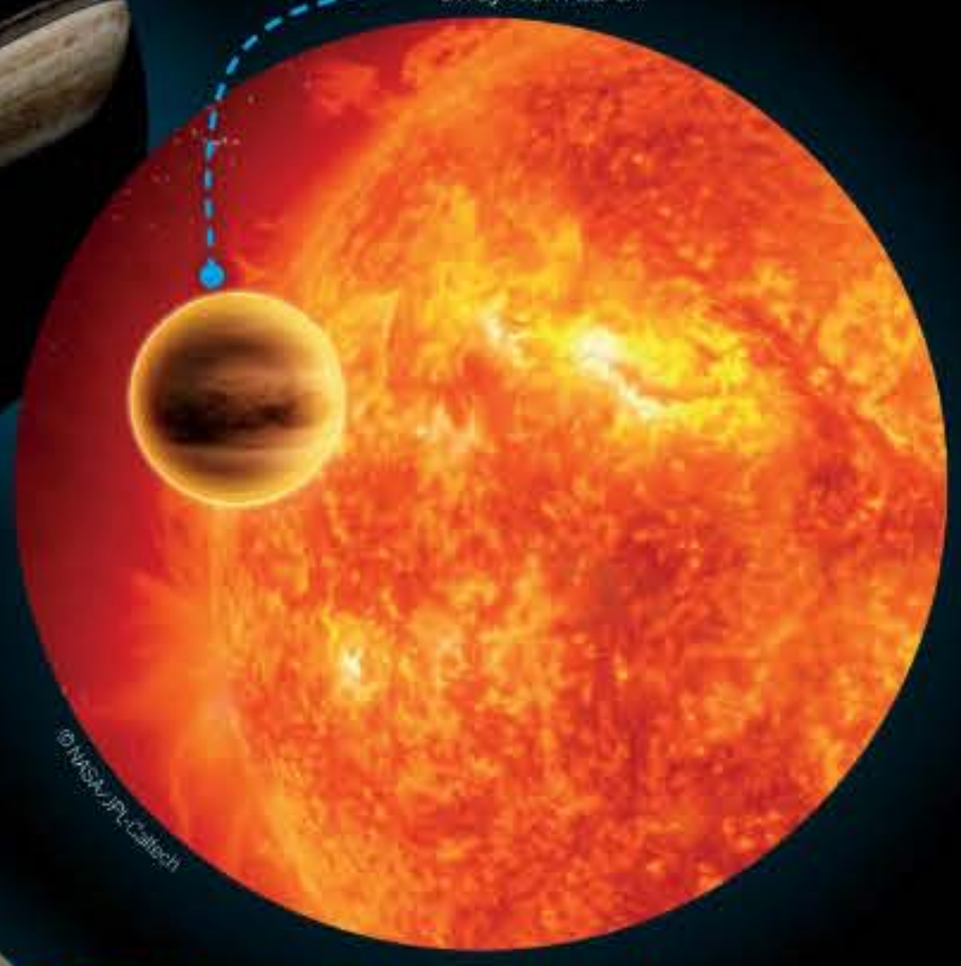


Source Wikimedia Commons/© Nuclear Vacuum

Tidally locked worlds

Planets that have one face continuously directed at the host star could circulate heat (provided it has an adequate atmosphere) and create a sweet spot between light and dark with Earth-like conditions.

Example world: 51 Pegasi b, roughly 50 light years away from Earth.



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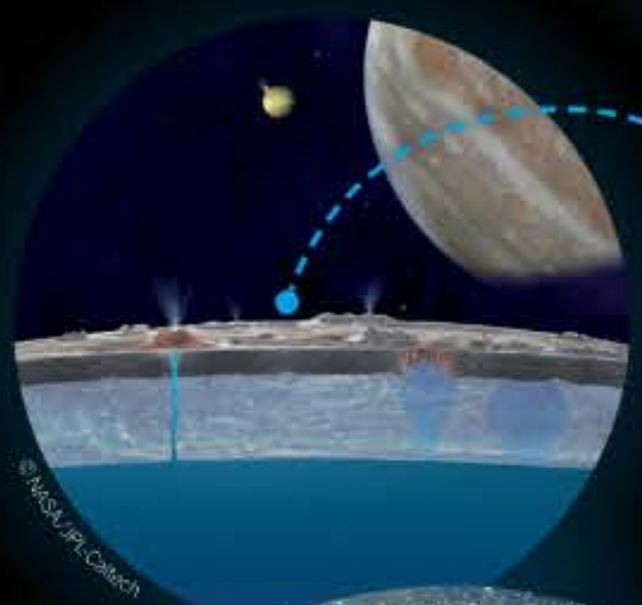
Yo-yo planets

Some exoplanets have extreme fluctuations in their seasons due to an elliptical orbit. The exoplanet could 'yo-yo' between blistering summers and shivering winters, but there could be periods in between where life could prosper.

Example world: 16 Cygni Bb, which is approximately 69 light years from Earth.



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Ocean worlds

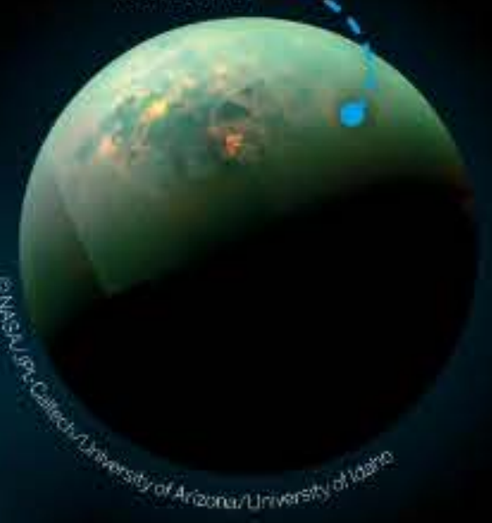
Worlds with an icy surface could have a global ocean underneath that harbours life and gets its energy from ocean floors, as opposed to starlight.

Example world: Jupiter's moon Europa, 35 light minutes away from Earth.

Liquid hydrocarbon worlds

For worlds that exist in colder temperatures than Earth, the same water cycle that was vital for the emergence of life on our world could occur with liquid hydrocarbons, such as methane or ethane.

Example world: Saturn's moon Titan is 1.3 light hours from Earth.



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Rogue planets

Whether it's due to a collision or stellar explosion, planets can be ejected into deep space. The planet's core could still fuel life while in darkness, much like ocean worlds.

Example world: PSO J318.5-22 does not orbit a parent star, roughly 80 light years away from Earth.

1 Gliding by
An exoplanet that has a thick atmosphere could drive its inhabitants to evolve to fly around, exerting as little force as possible as they glide through the planet's sky.

2 Non-stop flying
If aliens exhibit similar oxygen-transport systems in their bodies to Earth's life forms, a world with more oxygen could mean the creatures there fly non-stop.

3 Fixed wings
If an alien has a fixed-wing structure, with the wings only moving slightly for steering, then less muscle is needed and less energy is exerted when travelling through the sky.

4 The blind side
If a host planet is a rogue world with no host star to orbit and therefore no light, there is no need to see in the constant darkness, and aliens may evolve without eyes.

5 Hardened tusks
Mammals like elephants develop tusks for feeding and self-defence, which could be made bigger and stronger if the alien's host planet is abundant in calcium.

6 Energy source
Without sunlight, organisms need a substitute for photosynthesis; chemosynthesis. They could get energy through reactions with inorganic compounds.

7 A plant-animal hybrid
On other planets, hybrid organisms could find themselves having to relocate to different positions on a set of legs, in order to collect light and hydrate.

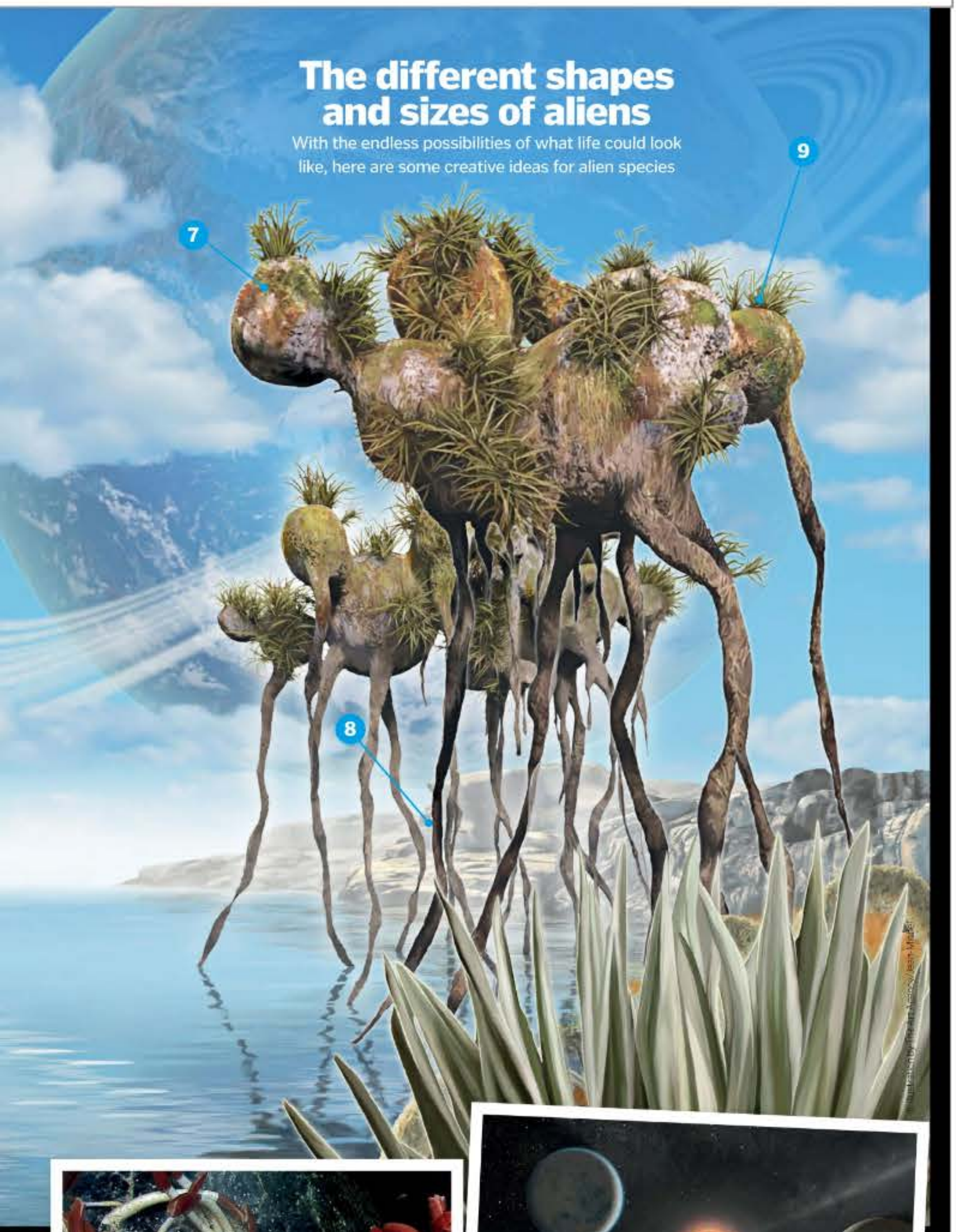
8 On the hunt for nutrients
Some alien life could evolve to shift between various locations to suck up the nutrients in a different spot across the planet's surface.

9 Survival of the fittest
If Charles Darwin's contribution to understanding evolution applies on other planets, these half-plant-half-animal creatures could develop a basic camouflage.

DID YOU KNOW? *There could be 100 billion planets in our galaxy alone*

The different shapes and sizes of aliens

With the endless possibilities of what life could look like, here are some creative ideas for alien species



Tube worms are living examples of life forms that don't depend on sunlight to survive

NASA's TESS mission will search for exoplanets smaller than Neptune orbiting nearby stars

Source: Wikimedia Commons

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Fox Fur Nebula

The nebula at the base of the tree is named due to its vulpine shape and textured appearance. Situated under the tree, its beauty serves as a pretty awesome gift for space observers. The vast quantities of interstellar matter are from photons emitted from hot, young stars.

Cone Nebula
Replacing the usual angel, at the apex of this tree sits the Cone Nebula. This pillar-shaped cloud flaunts an appropriately angelic halo around the top of the cone; a glowing ring of hydrogen that perfectly captures the light.

DID YOU KNOW? *Newborn stars at the centre of the Christmas Tree Cluster are a mere 100,000 years old*

The Christmas Tree Cluster

Scan the depths of our galaxy with a telescope and you may spot this festive cloud of star dust

Among the many festivities of Christmas, trees with twinkling lights that line the streets and stand in houses are a common sight. But one Christmas tree stands much further afield: shining roughly 2,600 light years away, it puts the centrepiece of our living rooms to shame. With fiery baubles furnishing its wispy shape, the Christmas Tree Cluster is a galactic display to behold.

As the largest Christmas tree in the universe, this formation of stars, dust and gas covers a width of about 30 light years with its natural sparkle. The cluster was first discovered in the 18th century, but modern telescopes can capture high-quality images like this one, using a series of filters to produce an electrifying assortment of colours. A bit of imagination and a tilt of your head is all you need to see how the Christmas Tree Cluster got its name.

So how does the triangle of galactic gas mimic these Christmassy shapes and tones? The bauble-like blue stars dispersed throughout the tree are actually young, hot stars that are more massive than our Sun. The tree's hazy red body is given its colour by its exposure to the ultraviolet light emitted by the 'baubles'.

Adhering to this magical theme, the festive cluster is found in the constellation of the unicorn (Monoceros), part of the NGC 2264 region. In clear conditions this spectacle is visible to the naked eye, with the brightest of its stars, known as S Monocerotis, bringing your gaze to the galactic tree's base.

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BRAIN DUMP

Because enquiring minds need to know...

Were there more volcanoes in prehistoric times?

Andrew Warren

The number of volcanic eruptions has certainly been higher during periods of Earth's prehistoric past than now. Around 200 million years ago, for example, scientists think that the break-up of the supercontinent of Pangaea triggered 600,000 years of intense volcanic activity that led to mass extinctions. **TL**

MEET THE EXPERTS

Who's answering your questions this month?


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TOM LEAN


LAURA MEARS


JAMES HORTON


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What happened to the crew who dropped atomic bombs on Japan in WWII?

Peng Lan

In August 1945 a US air crew dropped an atomic bomb on Hiroshima, instantly killing an estimated 80,000 people. Days later, another crew dropped a bomb on Nagasaki, immediately killing around 40,000 people. Both crews survived, and though they spoke of the devastation it caused, most said it saved lives in the long run by putting an end to the war. **JT**

Spacewalking astronauts are tethered to the ISS and often each other

What if an astronaut floated away from the ISS?

Isobel Adams

This is very unlikely to happen as all spacewalking astronauts are tethered to the ISS with a braided steel cable, but if the tether somehow failed, there is a backup option. The astronaut could use their Simplified Aid for Extra-vehicular Activity Rescue (SAFER), an emergency jetpack that could help them fly back to safety. This has a limited fuel supply though, so if that runs out, the other astronauts would need to launch a rescue mission. **JS**

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What are cryptocurrencies?

Emily Wilson

Cryptocurrencies are a form of hidden (crypto) money-like digital asset. They rely on swathes of interconnected computers to store information on the currency, such as how much a certain person owns. Some people like cryptocurrencies because they don't have any regulatory oversight – no bank or government can influence how much they're worth. Companies are making moves to have cryptocurrency used in exchange for a wide range of goods and services, but they're currently mostly purchased as an investment strategy by those who think their value will rise in the future. **JH**

What's the most massive exoplanet?

Jorge Luis Miranda

According to the NASA Exoplanet Catalogue, the most massive exoplanet is BD+20 2457 b, in the constellation Leo. It's a gas giant 55 times the mass of Jupiter, the most massive planet in our Solar System. **JS**

It's possible to sustain an injury when stretching, but pain can also be caused by contracting muscle spindles

© Getty

Can you injure yourself by stretching?

Imre Sebestyén

We all know how enjoyable it is to have a good stretch when we get out of bed in the morning. As well as being rewarding, stretching is an important part of exercise as it helps your muscles relax and begin to recover after intensive exercise. However, it's not unusual for stretching to cause a level of pain or discomfort. Most of the time this pain is caused by muscle spindles, which force your muscles to contract when you're at risk of over-stretching. This can cause a jolt of pain that dissuades you from hurting yourself. You can overcome the muscle-spindle tension by persisting with the stretch – but remember that this defence mechanism is there for a reason, as it is possible to both strain and tear a muscle when stretching. **JH**

An East India Company iron steam ship destroying Chinese war junks, 1841

© Alamy

What were the Opium Wars?

Laila Andersen

The Opium Wars of 1839-42 and 1856-60 were fought between Britain and Qing-dynasty China. They were a series of conflicts sparked over trade, drug trafficking and national honour. British people couldn't get enough of the tea, silks and porcelain that China had to offer, but the Chinese didn't want to purchase anything in return except opium. British merchants began smuggling the Indian-grown drug, until the Chinese forced them to hand over their stocks at the port. Britain demanded compensation, but when China refused to enter into diplomatic relations Britain returned with military might. Tens of thousands of Chinese were killed, but the British suffered only minor casualties. **JT**

© Getty

Is it safe to take expired medication?

Corey Knight

Expiration dates guarantee the potency and safety of medication, although this is debatable. One study found that 90 per cent of more than 100 drugs were fine to use 15 years later. However, it is best to always ask the advice of a pharmacist. **JT**

Did cavemen catch colds?

Christian Guzman

Today over 200 viruses can cause symptoms of the common cold. The most notorious of these are the rhinoviruses, which cause 30 to 50 per cent of all colds. Rhinoviruses evolved from enteroviruses, but viruses evolve so quickly it's difficult to know when this event occurred. This means that we can't be sure, but there's a chance our cavemen ancestors also caught the common cold. **JH**

© Getty

When is the next ice age?

Hollie Walker

According to a model by scientists from Northumbria University, we could be due a 'little ice age' as early as 2030. When this last happened in the 1600s, the Thames river froze over and there were 'frost fairs' held on the frozen water. **LM**

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Does Moore's law still apply?

Julian Wójcik

Moore's law refers to an observation made by Intel founder Gordon Moore in the 1960s. He noticed that the number of transistors on silicon chips was doubling every two years. Transistors are the miniature electronic switches that allow computers to make decisions. The more there are, the more powerful the computer, and the smaller they are, the more we can fit on a chip. The smallest transistors now measure less than seven nanometres. At that scale, electrons start to behave strangely, tunnelling between transistors and preventing the switches from turning off. Progress is slowing down as engineers get to grips with these quantum effects. **LM**

© iStock

Processing power has been increasing exponentially since the 1960s

© NASA

Can I buy a plot of land on the Moon?

Frank Patel

The Soviet Union and the US signed a treaty in 1967 that banned nations from claiming sovereignty over parts of the Moon. This doesn't necessarily apply to private companies, but no one has formally recognised ownership of any part of it. **JH**

BRAIN DUMP

© Getty

How do artichokes grow?

Aimee Robinson

Artichokes are a species of thistle native to the Mediterranean. The plant grows a wide wingspan of leaves and then thick stems grow upwards, producing flower buds on top in mid to late summer. The outer thorny petals of these buds can be removed to reveal the edible, creamy 'heart' inside. **JS**

Why are parts of the motorway covered in red tarmac?

Ashley Such

In some parts of the UK the nearby supplies of aggregates – the small stones used to make tarmac – include a lot of red-coloured rock. The result is red motorway tarmac. **LM**

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What is the 'dark net'?

Rosie Saunders

The dark net, or dark web, is a relatively small collection of websites that cannot be found using your usual search engine, such as Google, but instead requires special software to access. This special software is usually TOR (The Onion Router), although other software packages are available. It works by passing messages through a series of encrypted layers, a bit like a relay, to disguise the content and also protect the searcher's anonymity. The dark net can be useful for people wishing to bypass state censorship, but it is also used for criminal activity, such as buying and selling drugs or firearms. **JS**

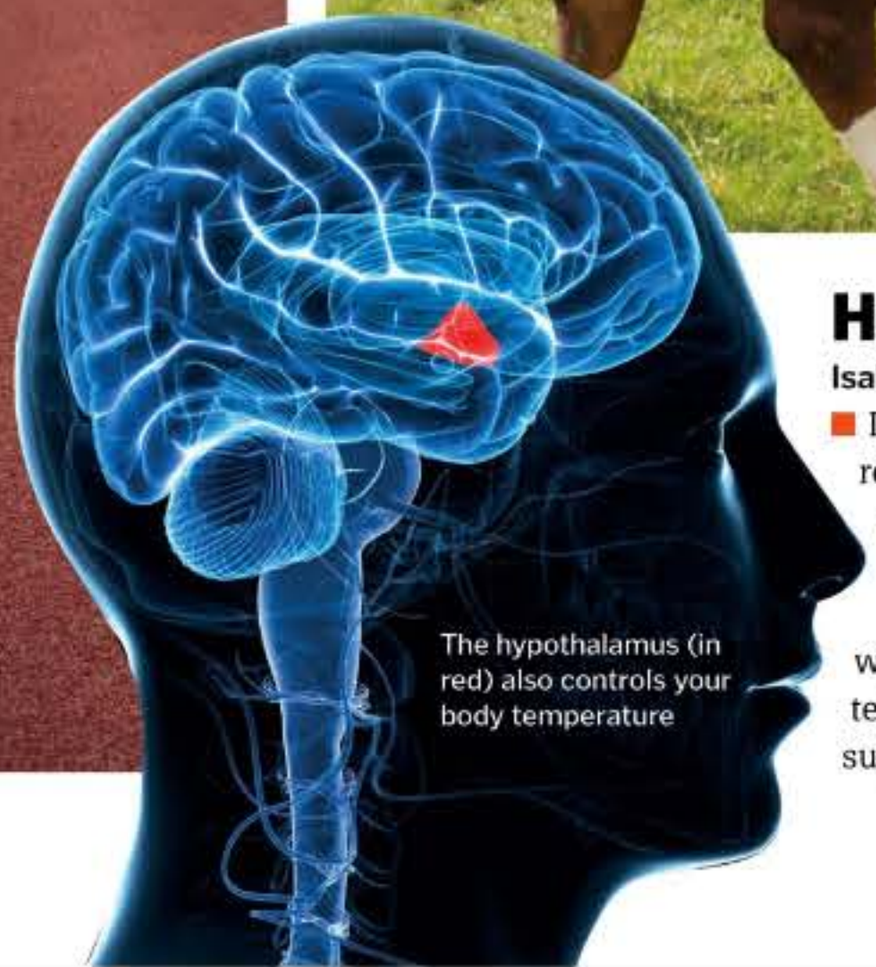
The dark net is a small part of the deep net, a wider collection of hidden webpages

What were farm animals like before domestication?

Jade Guerin

Over thousands of years, humans have greatly changed animals through selective breeding to make them suit our needs. Early sheep, for instance, had a short, coarse fleece, before new woolly breeds were created around 6,000 years ago. Many modern farm animals can grow faster and have more offspring than their ancestors, and they are often far larger. Early wild chickens, for example, weighed about 0.9 kilograms, but modern farmed chickens can weigh as much as 7.7 kilograms. **TL**

Humans have greatly changed farm animals over millennia to make them bigger and more productive



The hypothalamus (in red) also controls your body temperature

How do we know we are hungry?

Isabel Daniells

In the middle of your brain is the hypothalamus – a region responsible for important bodily processes, including food and water intake. Once your body has used up the energy from your last meal, your blood sugar levels drop. A hormone called ghrelin is produced in the stomach and stimulates hunger when it enters the brain. After you've eaten, different hormones tell your brain that you're full, and the feeling of hunger is suppressed until the cycle starts all over again. **JT**

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How do huge cruise ships stay afloat?

Keira Johnson

When a ship floats it presses down on the sea and displaces, or forces aside, water. Provided the ship displaces a weight of water equal to its own weight before it gets so low in the water that it sinks, then it will float, because the sea presses back up with an equivalent force. Cruise liners can weigh 200,000 tons but are designed with very broad hulls to displace a lot of water, meaning only a small part of them needs to be submerged for them to float. This enables them to have many decks of cabins towering high above the seas. **LM**

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A lot more of a cruise liner shows above the water than under the water

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Some people don't like the look of nose hair, but it does a really important job

© Getty

What is nose hair for?

Scott Palmer

Nose hairs protect the delicate respiratory system from irritants and infections. The long hairs just inside the nostrils are called vibrissae, and they act like a filter, catching large particles before they can enter the throat. They're supported by a second set of microscopic hairs called cilia. Cilia sweep sticky mucus back towards the throat, creating a conveyor belt of natural fly paper to trap smaller particles and germs. **LM**

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Can we run out of any elements on Earth?

Fred Lewis

In theory, yes. Earth's resources are finite. But it's likely that certain elements will just become very hard to find or too expensive to mine, rather than run out completely. The most abundant elements in Earth's crust are oxygen, silicon, aluminium, iron, calcium, sodium, potassium and magnesium. **LM**

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Splendor

Cover yourself in jewels, gold and renown to steal victory from your fellow merchants

■ Publisher: **Asmodee** ■ Price: **£34.99 / $39.99** ■ Number of players: **2-4** ■ Recommended age: **10+** ■ Typical game time: **30 minutes**

Splendor is a game of avarice and status, where you and up to three other players take the role of renaissance-era merchants, accumulating wealth to score prestige points. The 'board' is laid out in a 4x4 grid of cards, four from each of the three deck tiers laid horizontally, with one noble placed at the top of the board for each player, plus one extra. Each player starts with nothing, but can perform one of three actions on their turn: take three different gems of their choice, or two of the same gems. They can buy one of the cards on the board providing they have enough gems to cover its purchase cost (shown in the bottom left corner of the card), then replace it with another card drawn from the same tier. Or they can reserve a card from the board or one drawn from one of the decks, preventing other players from buying or reserving it themselves. Reserved cards are set to one side to be bought later, and the player also receives one gold piece.

Buying cards gives you access to a gem resource, indicated in the top right of the card. Each one reduces the cost of buying another card by one gem. For example, if you had one red and one green gem resource card, to buy another resource card that cost one black gem, one red gem and one green gem would only cost you one black gem. Each card you buy can also earn you prestige points, the number of which is indicated in the top left corner. The first to score 15 prestige points wins the game.

Visting nobles
Acquire enough gem cards, and you will receive a visit from a noble at the end of your turn, boosting prestige by the value at the top left of their card.

Top tier
Tier three cards cost the most gems to buy, but will also earn you the most prestige points.

All that glitters
Make a grab for as many gems as you can, but don't lose sight of your goal

Bottom tier
You should begin by buying the lower tier cards. Don't worry about prestige points to start with, as you'll need gem cards to buy the more valuable upper tier cards.

Take two
Only if a gem stack is at its maximum can you take two of the same colour on your turn.

Don't be greedy
You can only have a maximum of 10 tokens (including gold). If you've maxed out, you have to either exchange gems with the pool, or buy a card.

Gold fever
Gold tokens are wild – they can be used in place of any gem token. They're earned when you reserve a card, but you can only have a maximum of three reserved cards at a time.

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- Publisher: **Big Picture Press**
- Price: **£25 (approx $30)**
- Release: **Out now**

Exploring the human body has been an obsession for scientists for thousands of years. Understanding why people get sick, how they can be cured and how the body works has engrossed generations of enquiring minds. Now, with *Anatomicum*, you're invited to explore all of that information in one place.

The giant, thick pages give a really premium feel, and they're packed with beautiful, accurate and sometimes haunting illustrations, along with interesting facts about the human form. From tiny, individual cells, right up to the skeleton, skin and nerve system, it covers every part of the body.

At times, the design and illustrative style make this feel almost like it's been transported from Victorian times. Each section is opened with an illustration of the relevant body part – the skeleton, for example – drawn as if it's being presented in a wooden display case. It's clear that the goal here is to make the reader feel like they're strolling through the hallways of an old museum building, with each gallery they enter covering a new topic. It works really nicely, and while the point isn't laboured too heavily, it's a great way of making this feel more like an experience than a simple textbook. This is a museum that is open whenever you want to take a look inside.

The feeling is backed up by the writing, which is pitched nicely at young readers. The introduction – where Dr Jennifer Paxton talks about dissection of human bodies – isn't at all gruesome, but might raise some challenging questions for some parents. Still, there's no point denying the facts of the matter, as the vast majority of this book wouldn't be possible without these studies.

Beyond that, the book is absolutely stuffed full of interesting information. Readers will learn that the cardiovascular system pumps over 14,000 litres of blood around the body every single day, and that the epiglottis, a small fold of tissue in your throat, closes the windpipe as you swallow to stop food entering your lungs. It even explains what happens when things 'go down the wrong way' – it's the kind of information younger minds will absolutely lap up, making this a fantastic addition to anyone's collection.

★★★★★

Tyrannosaurus Rex: A Pop-Up Guide To Anatomy

Jumping right out at you

- Author: **Dougal Dixon, Rachel Caldwell**
- Publisher: **Templar Books**
- Price: **£25 (approx $30)**
- Release: **Out now**

We didn't realise just how much we missed pop-up books until this one fell into our laps. Of course, an inventive format requires a similarly remarkable subject matter, and there are few more evocative topics than dinosaurs. Picking the *Tyrannosaurus rex* as their subject matter, Dougal Dixon and Rachel Caldwell set about delving into what makes the king of the dinosaurs tick, diving into the different parts of its body and setting out their findings in pop-up form. Each page is annotated for extra detail, and each popout contains extra layers that go beyond the conventions of the format.

Moving from the head, senses and abdomen to the legs and tail, it is to the authors' credit that they've managed to present their knowledge in such a way, bringing the subject to life. As a learning aid, we can't praise this highly enough.

Primarily this is aimed at children, with the large fonts and bite-sized sentences making this perfectly accessible. And the popouts aren't just there for decorative purposes; sufficient detail is covered on the function of each body part. Nothing that's included is in any way superfluous.

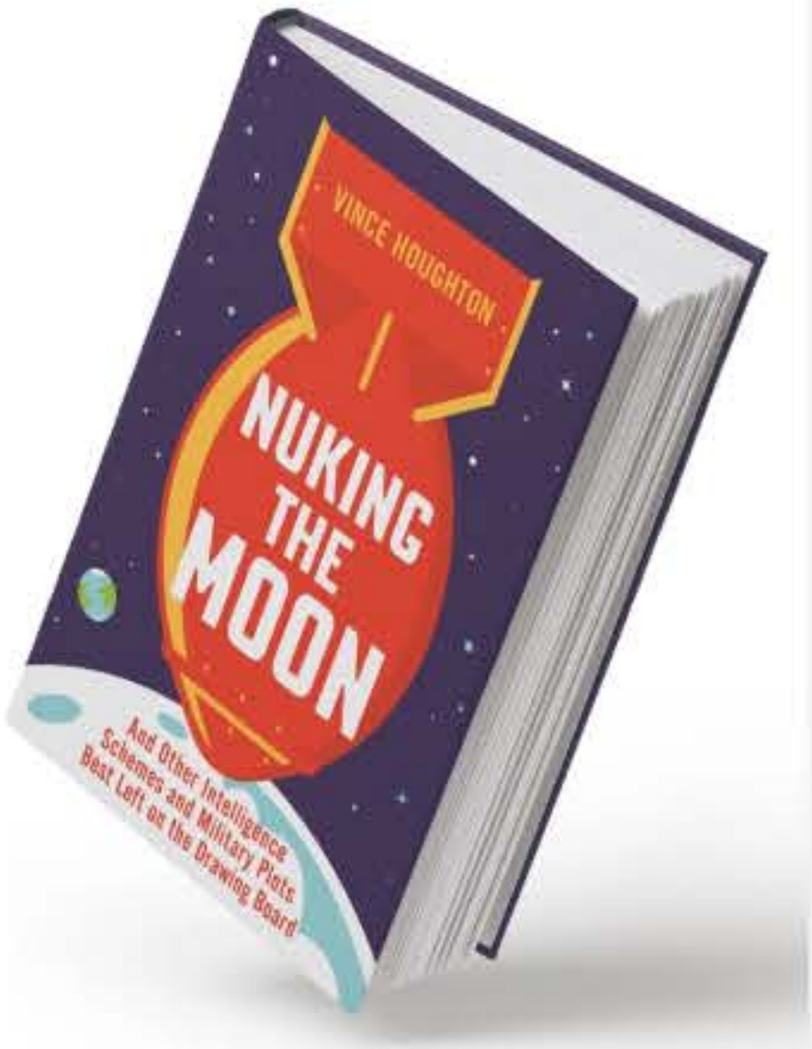
So if you're looking for something to add bite to this year's Christmas stocking, you've found the right beast.

★★★★★

Nuking The Moon

What thankfully never was

- Author: **Vince Houghton**
- Publisher: **Profile Books**
- Price: **£9.99 (approx $15)**
- Release: **Out now**



Named after an actual mooted plan (we're not going to give away the juicy details here), *Nuking The Moon* presents an amusing counterpart. So often have we lionised accounts of humanity's greatest achievements in these pages, it turns out to be a silent delight that we can hear accounts of our less-than-impressive ideas, while taking comfort in the fact that, for the most part, nothing bearing any resemblance to them ultimately came to fruition.

With Vince Houghton – curator of the International Spy Museum, no less – lending credence to these fantastical follies, there is a wide breadth of balderdash to get through. From the as-ridiculous-as-it-sounds Project Fantasia, to poison-toting Chinese call girls and the advent of the Dyna-Soar (just wait until you hear about that one), there's a lot of idiocy in these pages to admire, and all of it's given the gloss of Houghton's natural wit.

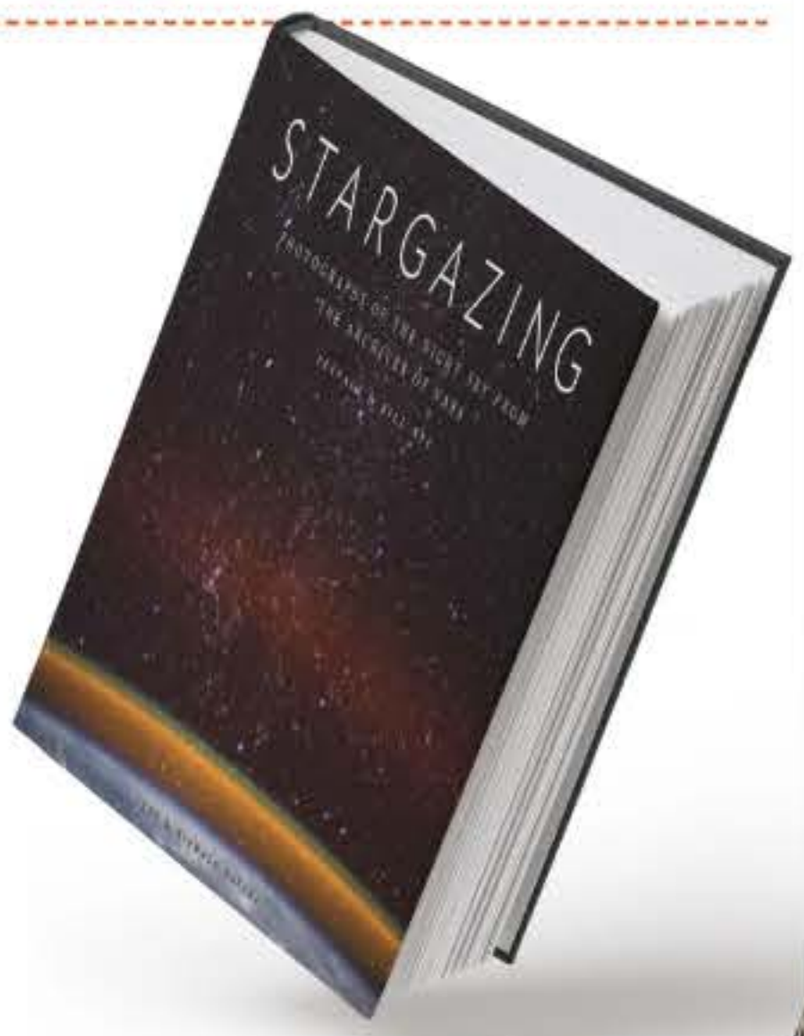
Considering the state of political discourse today, it's becoming increasingly hard to shock, which in itself can be seen as a source of gloom. Regardless, if you take nothing else from this book, it's the fact that things could be a hell of a lot worse. At least there's some entertainment thrown into the bargain.

★★★★☆

Stargazing

Up there

- Author: **Nirmala Nataraj**
- Publisher: **Chronicle Books**
- Price: **£25 / $35**
- Release: **Out now**



We do love a bit of gazing into the skies, but the weather being what it is in the UK, we don't always have the most comfortable conditions to do so. It's a good thing, then, that books like this exist, allowing us to travel to far-away places while it's raining cats and dogs outside. Here we can take our time to glance at some particularly remarkable examples from NASA's own archives, taking in views from all over the world – and even outside of it, in the case of the International Space Station. In the process all sorts of phenomena are captured, from aurorae and comets to noctilucent clouds and the Flaming Star Nebula.

Both as a repository of humanity's space-faring discoveries and as an aspirational guide for budding sky-watchers, there are numerous appealing facets to this guide. It's definitely one to pick up as a coffee-table read, and not just on a solitary occasion.

★★★★☆

"For budding sky-watchers, there are numerous appealing facets"

Living Iron

Heavy metal

- Authors: **Vanessa Everts, Pauline van Lynden**
- Publisher: **Visual Legacy**
- Price: **£36 (approx $45)**
- Release: **Out now**

We'll be completely honest here: of all the books we were given to review this month, this is probably the one we were least excited about. After all, how exciting can iron be?

It turns out, rather surprisingly, that the answer is 'quite a lot'. To chart the history of iron is to follow the history of Earth. From the dawn of time itself to modern manufacturing, authors Vanessa Everts and Pauline van Lynden put forward an impressively compelling case for iron's influence. Exactly what these are, you'll just have to read and discover for yourself.

Even if you have absolutely no interest in it (as we thought about ourselves), you might well find it hard to turn away. With a bit of luck, Everts and van Lynden will find themselves working through the periodic table in a similar manner. We can but dream...

★★★★★

BRAIN GYM

GIVE YOUR BRAIN A PUZZLE WORKOUT

Wordsearch

W	E	V	V	E	A	X	L	L	B	E	N	E	E	F
X	F	E	R	R	O	F	L	U	I	D	E	I	M	O
S	S	D	G	N	G	O	U	R	X	D	B	E	X	S
I	L	X	A	R	C	O	L	O	G	Y	U	L	L	S
G	H	T	L	F	U	L	P	R	O	D	L	X	A	I
S	S	E	L	X	M	A	J	N	D	E	A	E	R	L
W	W	H	I	O	I	S	O	X	H	X	W	O	I	X
I	N	I	U	X	L	I	U	C	F	R	E	D	M	N
T	E	V	M	E	T	R	N	W	I	M	G	I	D	A
C	E	R	A	U	F	A	W	O	P	S	E	L	A	B
H	W	X	L	E	L	X	O	X	L	R	S	W	E	E
E	S	O	X	A	U	E	R	L	T	T	O	I	L	T
L	V	E	V	S	S	U	M	N	W	A	N	T	T	E
E	X	A	C	I	R	P	X	S	E	M	A	J	O	D
X	N	I	C	H	O	L	A	S	E	C	I	R	P	N

FIND THE FOLLOWING WORDS...

GALLIUM
FERROFLUID
PROTON
AVALANCHE
FOSSIL
ARCOLOGY
SWITCH
NICHOLAS
ADMIRAL
EVOLUTION
NEBULA
WORM

Quickfire questions

Q1 Which metal is used in thermometers?

- Gallium
- Mercury
- Iron
- Plutonium

Q2 Which fish was thought to be extinct until found in 1938?

- Coelacanth
- Megalodon
- Sockeye salmon
- Silver trout

Q3 Which of these is not another name for Father Christmas?

- St Nicholas
- Old Christmas
- Beelzebub
- Santa Claus

Q4 What's the typical speed of an avalanche?

- 16 kph
- 320 kph
- 130 kph
- 8 kph

Spot the difference

See if you can find all six changes we've made to the image on the right

Sudoku

Complete the grid so that each row, column and 3x3 box contains the numbers 1 to 9

EASY

2		1	5	4				6
		5	6		2	1	3	
		8	3				5	7
8		4		3			7	2
3	9	2	4	7		6		
		6	9		8	5	4	
5	2	3		6		4		
		9						1
1	6						2	

DIFFICULT

3								4
2			8	9		6		
8			6				2	1
	1				4			
		6					9	
		3				2		
6					1			5
9		4			7	1		
	5	8			6			

What is it?

Hint: Watch this space! Earth's sky is not the limit.

A .....

© NASA

Spot the difference

Check your answers

Find the solutions to last issue's puzzle pages

Quickfire questions

Q1 Stimulated

Q2 1961

Q3 Endeavour

Q4 1.425 billion tons

What was it?

Human embryo

HOW TO...

Practical projects to try at home

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Make a giant salt crystal

Use the chemistry of crystallisation to form an enormous salt crystal at home

1 Dissolve the salt

First, ask an adult to heat around 500ml of water in a kettle. Pour it into a container, then add salt and stir it until it's all dissolved. Keep adding salt to the water until it's saturated.

2 Colour or clear?

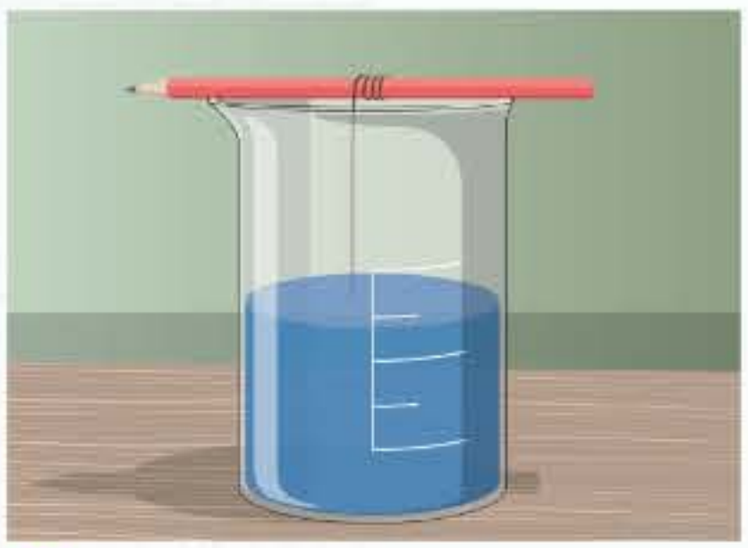
If you want to make a coloured crystal, you can also add a few drops of food colouring to your liquid. Alternatively you can leave it clear to make a white crystal.

3 Find your crystal

Leave the mixture for a few days until crystals form at the bottom of the container. Pour the mixture into another container, then scrape out the crystals and choose a large, smooth one.

4 Filter and cool

Take the remaining solution and pour it through a filter to remove any impurities. Tie a string around the crystal you took out and hang it from a pencil so it rests in the solution.

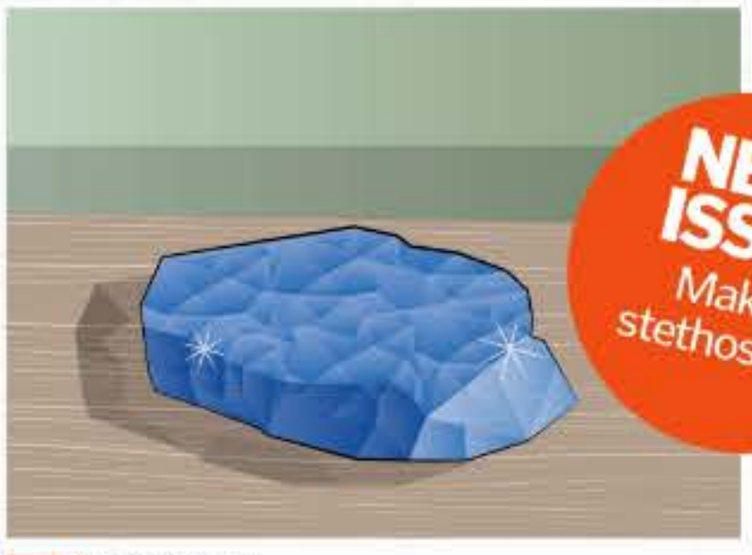


5 Start the process

Leave the mixture for a few days, and the crystal should start to grow as it attracts more salt particles from the solution. Try putting it in a cool place to speed things up.

6 Keep filtering

Every five days, take the crystal out and filter the solution again. This should remove any impurities in the water and ensure your crystal is pure salt.



NEXT ISSUE
Make a stethoscope

7 Wait it out

The longer you leave the solution, the larger your crystal will get. After around a month, you should have a crystal that is big enough to take out and display.

8 Polish your crystal

To preserve your crystal and avoid it absorbing moisture, paint the whole thing with transparent nail polish to create a protective barrier around the salt.

SUMMARY...

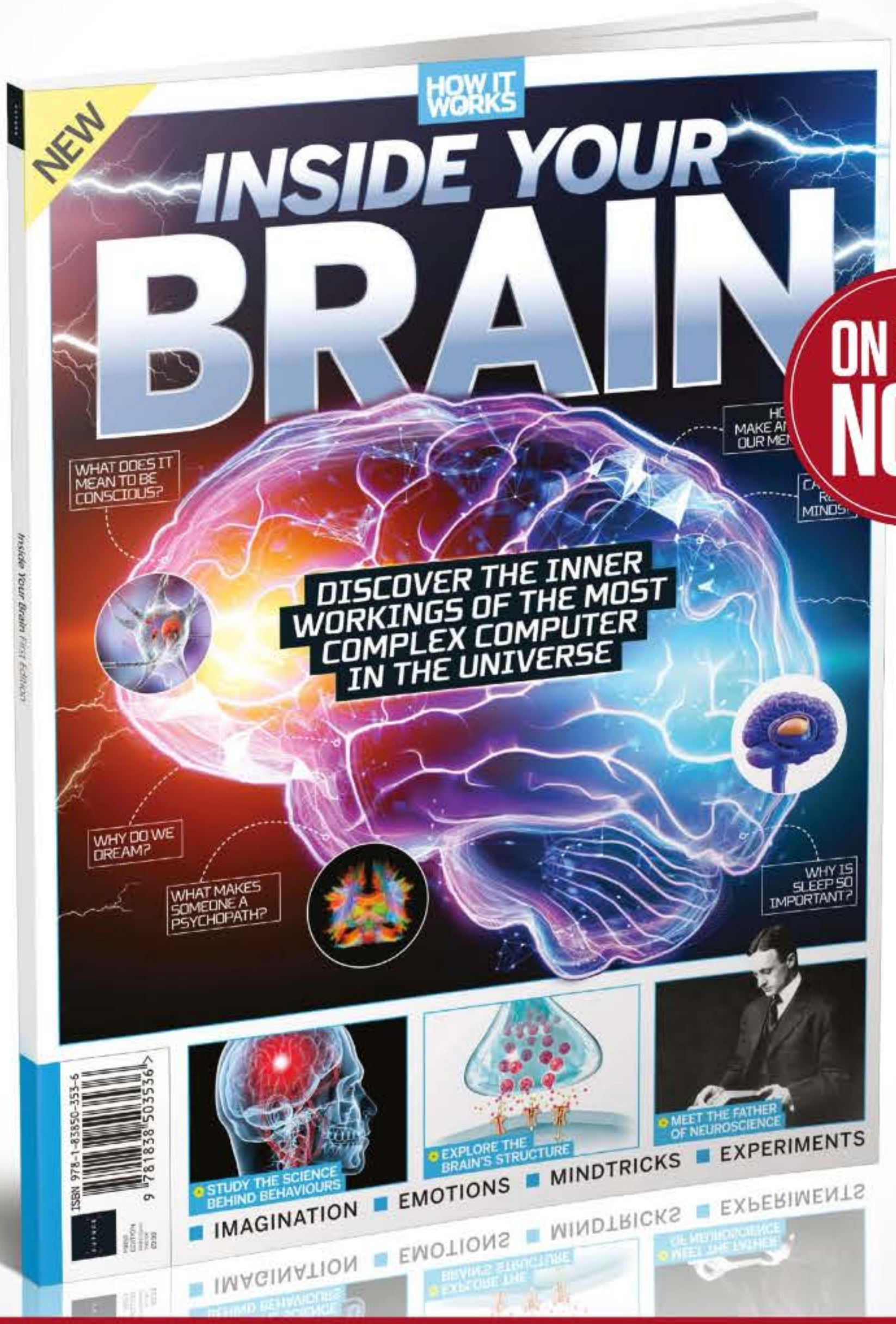
When you dissolve table salt (sodium chloride) in water the sodium and chlorine atoms separate. Warm water can dissolve more salt than cool water, so when the water starts to cool, the two atoms reform into crystals. If there's already a crystal in the solution, this attracts the newly formed atoms, making that crystal grow.

Had a go? Let us know!

If you've tried out any of our experiments – or conducted some of your own – then let us know! Share your photos or videos with us on social media.

EXPLORE THE MANY WONDERS OF THE HUMAN BRAIN

Have you ever wondered why we dream? Confused by what it means to be conscious? Intrigued by the latest cutting-edge brain technology? Well wonder no more, for all the answers to your brain questions can be found in this book!



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© Getty

Busy planet

Dear **HIW,**

The following question spawned from a conversation with my 6-year-old son. If everybody who was born had never died, how much of the Earth's land today would be occupied; either standing side by side, or with an assumed living space footprint area?

Martin

To answer this, we will focus on 'modern' *Homo sapiens*. This being said, if nobody ever died, we would have a great living demonstration of our species' evolution. *Homo sapiens* first walked the Earth around 300,000 years ago, and since then over 100 billion people have been born. Today there are about four additions to our species every second.

It is impossible to determine exactly how many people have ever lived, as there aren't records throughout the entire human existence. However, we can use assumptions about history to predict populations.

A recent estimation in 2017 suggested that the number of people that had ever lived at that time was 108,470,690,115. While this was two years ago, if we assume the average of 130 million births each year to be true, we can slightly alter the estimate to say that 108,730,690,115 people ever existed.

If everyone stood together, using one square metre as the average standing space, this would be over 100 billion metres squared. The Earth's surface area is 510 billion square metres. This means that around one-fifth of the planet would be completely covered.

Letter of the month

Head or heart?

Dear **HIW,**

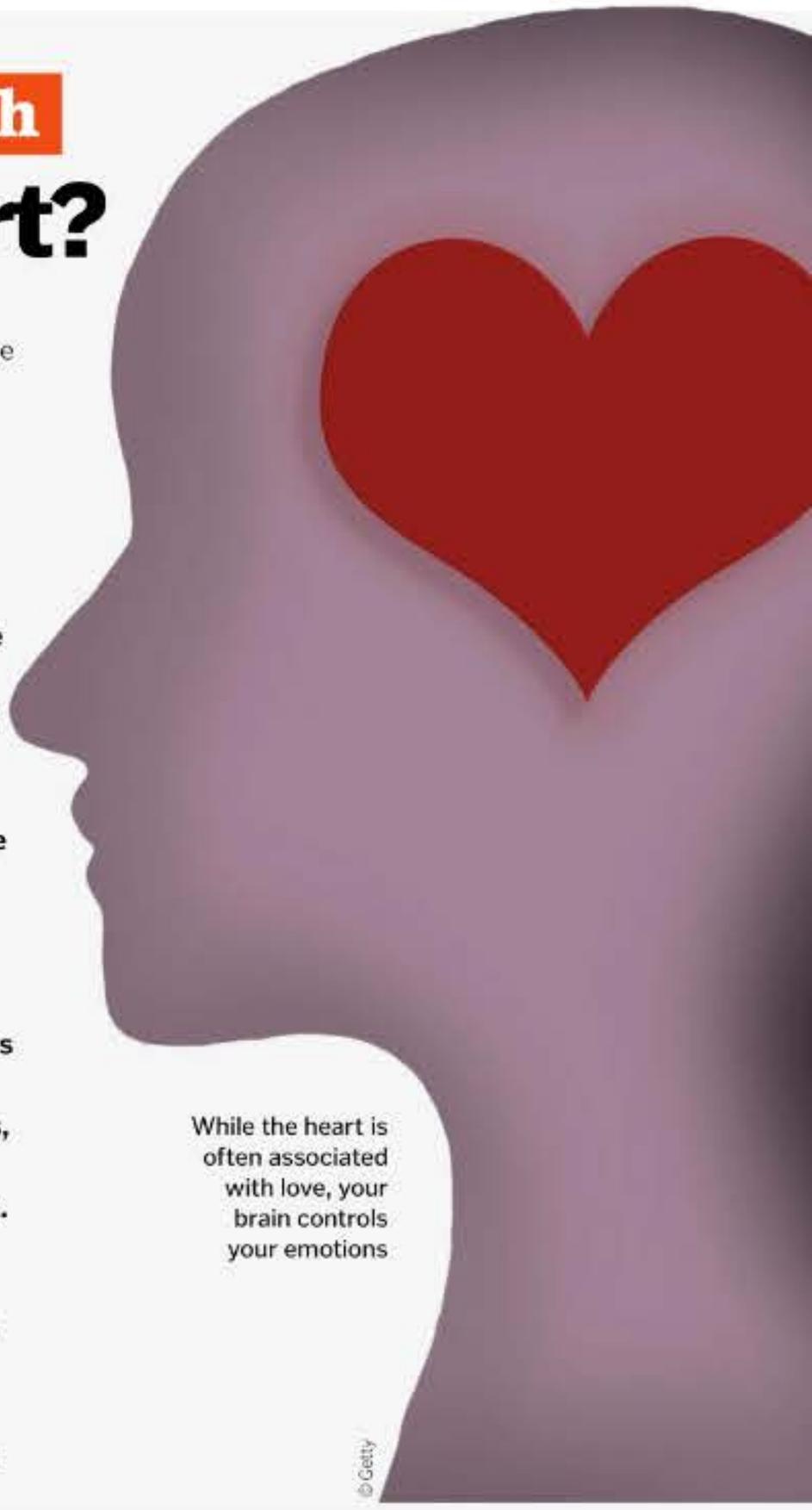
When you like or love someone, is it a matter of the heart or of the brain, or both? Please also explain how they are connected to our feelings.

Esme

Whether to follow your head or your heart is a commonly stated predicament, but which would make the real difference? The heart has been a symbol associated with love for centuries, but it is in fact our brain that creates the thoughts and feelings we experience during love. The link between the heart and love can be dated back to the ancient Egyptians. Their belief was that it was the heart, rather than the brain, that was responsible for all wisdom, emotion, memory, personality and soul.

It is the production of different hormones that play a role in creating emotions. The heart may be involved with some emotions, however, as hormones can be produced anywhere in the body – including the heart.

It is your brain that is flooded with the hormone oxytocin during romance. Dopamine, phenylethylamine and oxytocin enter the bloodstream when you see someone you are attracted to. These chemicals keep your body alert for a short period, causing your heart to beat faster.


While the heart is often associated with love, your brain controls your emotions
© Getty


Sirius A can clearly be seen throughout winter nights in the northern hemisphere
© Getty

The brightest star

Dear **HIW,**

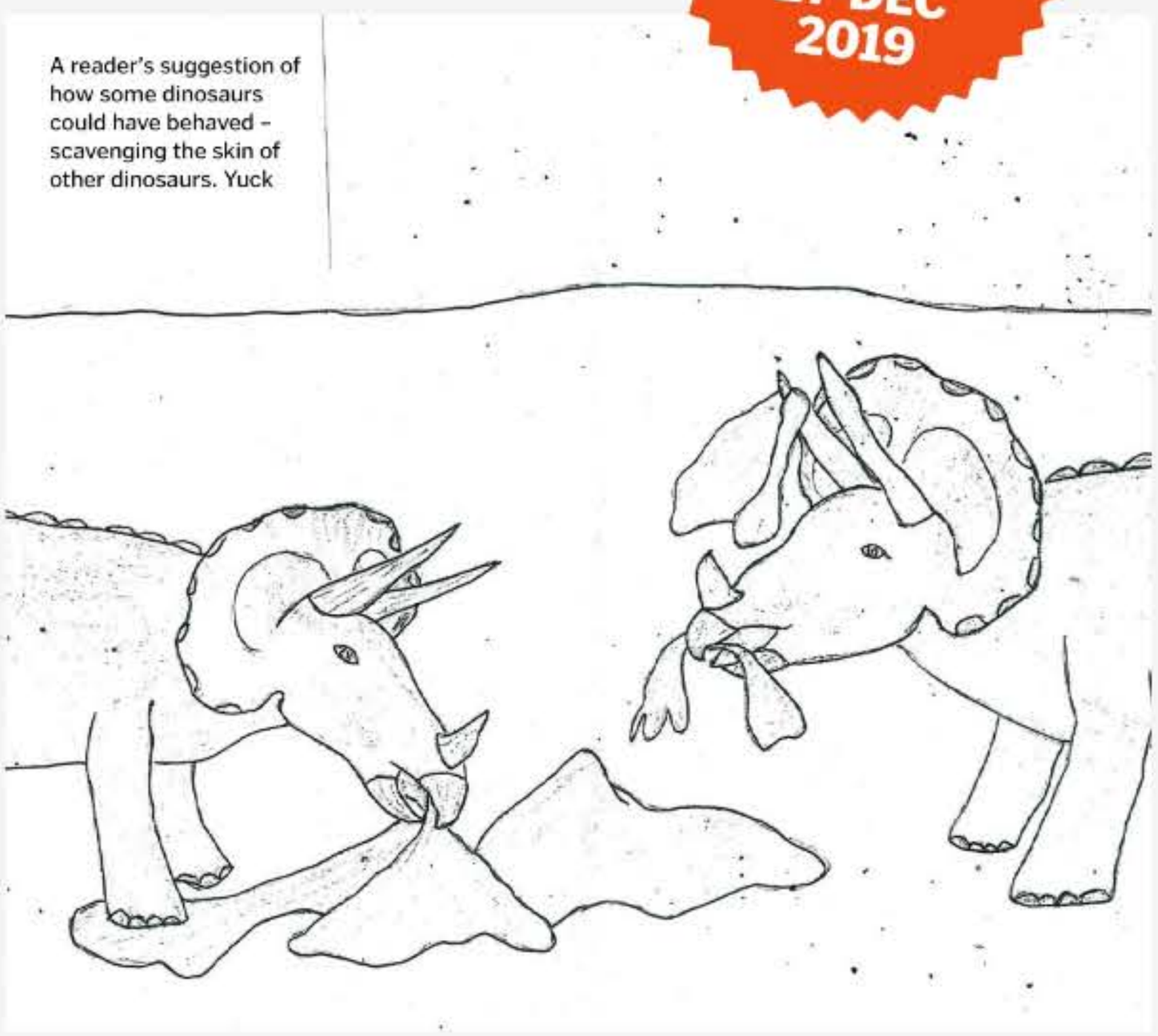
What is the brightest star in the sky?

Will Thorne

The brightest star in the sky is called Sirius A – its fitting name means 'glowing' in Greek. Sirius is nicknamed the 'Dog Star' because it is part of the Canis Major constellation. This constellation translates from Latin to mean 'the greater dog'.

The star has been observed and acknowledged since ancient times, and today it can be visibly seen throughout winter in the northern hemisphere. Standing out from the dimmer stars surrounding it, it became a basis of the ancient Egyptians' calendar as they used the times when it first became visible in the sky to determine the start of the calendar year.

WIN!
30-SECOND PHYSICS
This book tackles the big ideas behind life as we know it; from electromagnetic waves that connect us from opposite sides of the Earth to the gravity that keeps our feet firmly on the ground.



A reader's suggestion of how some dinosaurs could have behaved – scavenging the skin of other dinosaurs. Yuck

Skin-eating dinos?

Dear **HIW**,

This is an idea I have about dinosaurs. Being reptiles, they shed their skin as they grew and there was a whole group of dinosaurs which ate the skins. Any dinosaur with a beak, horns, armour-plating, spikes, plates on its back, a neck crest or thumb spikes was a skin-eater.

The following would therefore, have been skin eaters: Triceratops, Iguanodon, Stegosaurus and Ankylosaurus.

They would have used their horns etc. to shred the skins before they ate them. I imagine skin-eaters were well-tolerated by the other dinosaurs as they plodded around scavenging the skins.

Anonymous

Thank you for your letter and impressive drawing. When looking into the history of dinosaurs, scientists are unable to study a living example of these creatures. So while we can depict a relatively accurate picture of what these creatures may have looked like, their behaviour is difficult to pin down. Speculations based on known facts, analysing their fossils and the similar traits in modern animals allows us to imagine what their lives and purpose may have been – similar to how you have!

What's happening on... social media?

This month we asked you what unusual traditions you hold during this festive period.

@radders2012

"We sing the 'Piggies in a blanket' song when the pigs in blankets are brought to the table!"

@helenharding83

"We always have to have our tree up on 1st December"

HOW IT WORKS

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FAST FACTS

Amazing trivia to blow your mind

2 MILLION

SOLERI'S MESA CITY, A DESERT ARCOLOGY, WAS DESIGNED TO ACCOMMODATE AS MANY PEOPLE AS A MODERN CAPITAL

-272.2 CELSIUS

HELIUM ONLY FREEZES AT AN INCREDIBLY LOW TEMPERATURE, NEAR ABSOLUTE ZERO (-273.15 CELSIUS)

402.3 KPH

THE 1980 VOLCANIC EXPLOSION OF MOUNT ST HELENS TRIGGERED THE WORLD'S FASTEST RECORDED AVALANCHE

5,067 YEARS

A BRISTLECONE PINE TREE IN CALIFORNIA IS THE WORLD'S OLDEST INDIVIDUAL ORGANISM

9KM

A SINGLE GRAM OF THE SYNTHETIC SPIDER SILK, FIBROIN, CAN BE SPUN INTO A VERY LONG STRAND

AROUND 500 GAMMA-RAY FLASHES ARE DETECTED IN EARTH'S ATMOSPHERE EVERY DAY

15%

GAS AND DUST BETWEEN STARS MAKES UP A SIGNIFICANT AMOUNT OF THE MILKY WAY'S VISIBLE MASS

4 GIGABYTES

NINTENDO'S SWITCH LITE HAS 2,000,000 TIMES THE MEMORY OF THE 1983 NINTENDO ENTERTAINMENT SYSTEM

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QUEEN ELIZABETH-CLASS ROYAL NAVY AIRCRAFT CARRIERS DISPLACE A HUGE AMOUNT OF WATER

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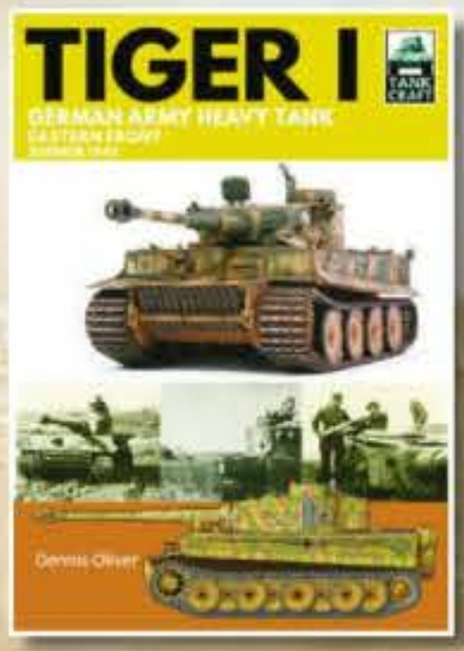

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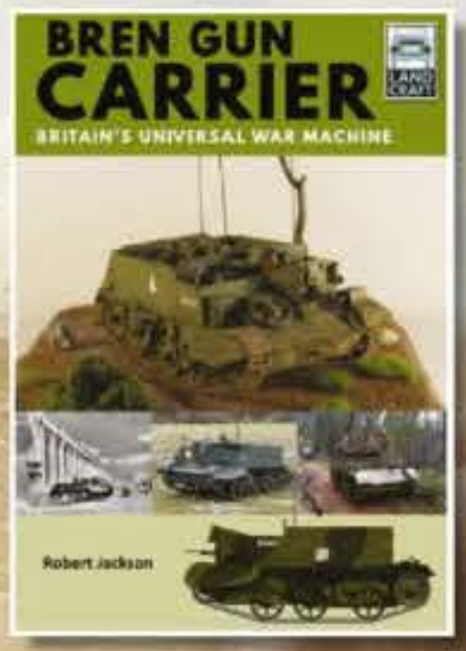

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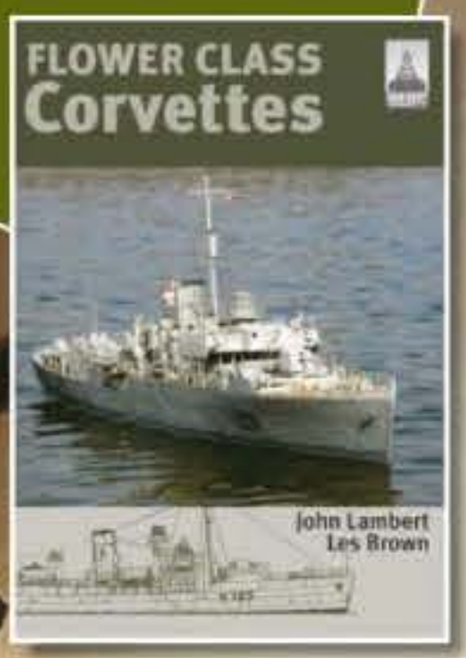

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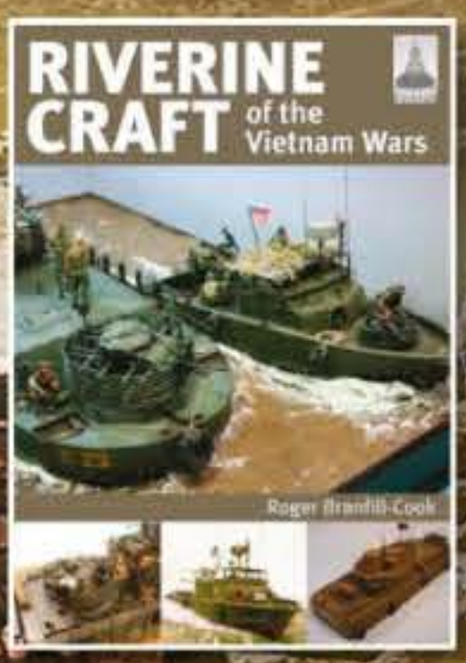

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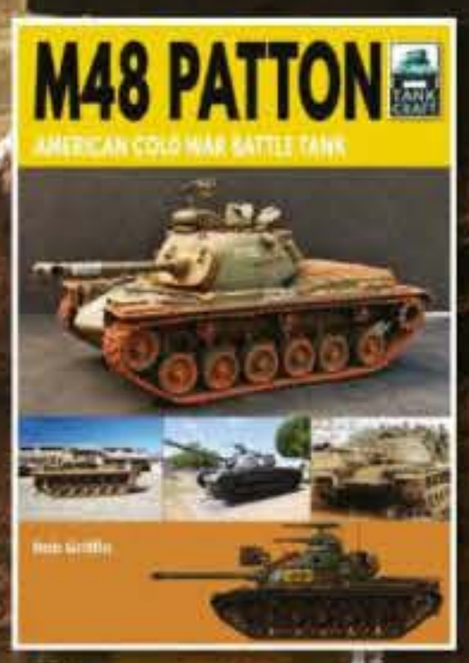

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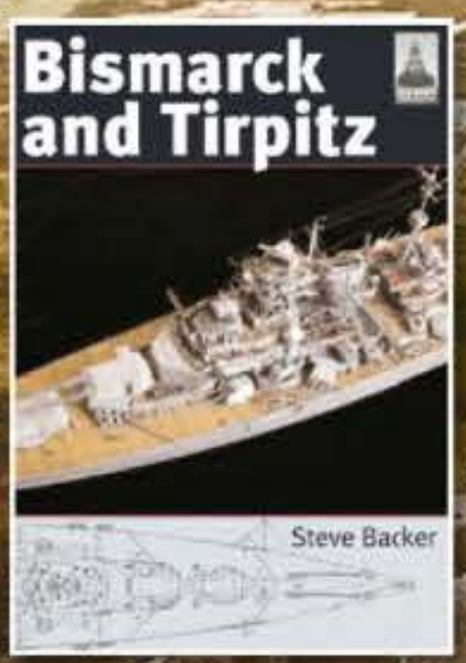

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